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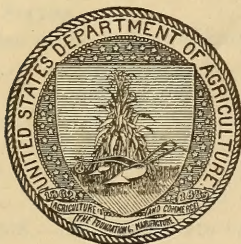
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THE FLOW OF WATER IN WOOD-STAVE PIPE.

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INTRODUCTION.

During the past 10 or 15 years the use of wood pipe for the conveyance of water has been greatly increased. Such pipe is now quite commonly used to convey water for the irrigation of land, the domestic needs of towns and cities, and the development of power. So long as wood pipe consisted of bored logs its carrying capacity was limited to a small flow and its adaptation to a limited set of conditions, but the conversion of clear, sound lumber into staves and the making of stave pipe into sizes from 12 to 72 inches in diameter led to a great expansion in both carrying capacities and uses. More recently it has been found that stave pipe can be successfully built

NOTE.—This bulletin treats of the subject of flowing water in wood-stave pipes. It is based on field tests made on pipes in commercial operation. New formulas are developed that more accurately fit all known data than any others now used. This publication is offered for use of engineers designing and measuring wood-stave pipes for irrigation, power, municipal, mining, or other purposes and for courts and attorneys at law interested in cases involving the carrying capacities of wood-stave pipes.

and operated in sizes up to 12 and 13 feet in diameter, the largest to date being 13½ feet. This great increase in size and carrying capacity has been brought about by providing yokes or cradles which support the lower part of the pipe and thus prevent its collapse.

Being well adapted to low heads and large diameters, such pipe has proved one of the best and cheapest means of conducting large volumes of water under low or medium heads from the sources of supply to the places of use, regardless of whether the latter be a power plant, a storage reservoir, the highest portion of an irrigated tract, or the distributing reservoir of a municipality. Stave pipe is also frequently used in the construction of inverted siphons, so called, in conjunction with canals and grade pipe lines, to convey water across gulches, ravines, or other depressions or down chute drops to lower levels. It is likewise well adapted to rolling ground where the building of canals on grade might be impracticable. Finally, in the smaller sizes it is often used to convey and distribute water to orchard tracts, manufacturing plants, and municipalities.

The present economic importance of stave pipe in this country, which arises from its adaptation to so many diverse uses, its wide range of capacities, the ease with which it can be laid on rough ground, and its cheapness when compared with other pressure pipes, has led this department to investigate and report upon its merits and demerits. About three years ago a study was begun which comprised the types, materials, methods of construction, and durability of wood pipe. The results of this study were summarized in a recent department bulletin.¹ During the past two years another phase of the same general subject has been investigated. This investigation has included the making of tests and the collection of data on the flow of water in wood-stave pipe, the results of which are embodied in this report. Field work during the summer seasons of 1914 and 1915 consisted in the performance of 64 experiments on the flow of water in wood-stave pipes ranging in diameters from 8 inches to 13½ feet, while the office work consisted in the collection and analysis of available records of all previous experiments of a similar character and the preparation of the data herein presented. From the results of all experiments made, which combined reach a total of 286, there has been deduced a new set of formulas for the flow of water in stave pipe which is here presented. (See p. 48.)

In another publication² the writer has endeavored to show that Kutter's formula is applicable to the design of any open channel and that the recommendations of the earlier writers on this subject concerning the values of n (which comprises all the influences retarding

¹ Wood Pipe for Conveying Water for Irrigation, by S. O. Jayne, Bulletin 155, U. S. Department of Agriculture.

² The Flow of Water in Irrigation Channels, by Fred. C. Scobey, Bulletin 194, U. S. Department of Agriculture.

the flow) were in the main correct. But a thorough study of the flow of water in pipes, and more particularly wood-stave and concrete pipes, has convinced him that Kutter's formula is not best adapted to flow through pipes running full and under pressure. The work of recent experimenters indicates that the exponential type of formula is best adapted to such flow. Therefore the new formula is of the exponential type.

Much uncertainty has existed in the minds of hydraulic engineers during the past 30 years with regard to the carrying capacities of stave pipe. If the new formula helps to clear up former uncertainties and give to those engaged in the design and operation of stave pipes a reliable guide by which to determine flow through such conduits, it will have served its purpose.

NOMENCLATURE.

Unless otherwise noted, the various symbols used throughout this publication will have the following significance:

d—The mean inside diameter of the pipe in inches.

D—The mean inside diameter of the pipe in feet.

r—The mean inside radius of the pipe, or $\frac{1}{2}D$, in feet.

Q—The mean discharge of the pipe, during the test, in second-feet.

A—The mean area of the pipe bore, in square feet, $=\pi r^2$.

V—The mean velocity of the water, during the test, in feet per second.

L—The length of reach tested, in feet.

h_f —The head of elevation lost in overcoming internal resistances within a fairly straight pipe of uniform size, in feet, $=\frac{HL}{1000}$.

H—The above loss (termed friction loss) per 1,000 linear feet of pipe, $=\frac{1000 h_f}{L}$.

h_v —The head of elevation lost in creating the mean velocity, V, in feet. Called velocity head.

h_v' —The velocity head recovered as the velocity is reduced at the pipe outlet, in feet.

h_e —The head of elevation lost at a pipe intake due to impact and entrance resistances, in feet, here called entry head.

P—The wetted perimeter; in a pipe under pressure, the inside circumference, $=\pi D$ or $2\pi r$, in feet.

R—The hydraulic radius, $=\frac{A}{P}$; in a circular pipe, under pressure, $=\frac{D}{4}$.

s—The hydraulic grade or slope, in feet per foot of length of a pipe of uniform size, $=\frac{h_f}{L}$.

n—The coefficient of retardation in Kutter's formula.

C—The coefficient of retardation in Chezy's formula.

C_w —The coefficient of retardation in the Williams-Hazen formula. Not to be confused with C in the Chezy formula.

f—The coefficient of retardation in the Weisbach formula. (This formula is variously known as Weisbach's, Weston's, Darcy's, and Chezy's.) (See p. 6.)

$H=m V^2$.—The general equation for the flow of water in a pipe, in which m is the intercept on the vertical axis and z is the slope of the line, expressed as the tangent of the angle between the line and the horizontal axis. (See equation 17, p. 49.)

$m = K d^x$.—The equation for the variation in m for a series of pipes of various sizes but with the same characteristics; K is the intercept on the vertical axis, and x is the slope of the line, when values of m are plotted as ordinates and values of d as abscissæ. (See equation 19, p. 49.)

m' .—The special values of m found for each series of pipes, by drawing lines from the centers of gravity for the observations in each series, at a constant slope, to an intersection with the vertical axis.

No. —.—Wherever a pipe number is given, the reference is to the corresponding number in Tables 2 and 3, to Plate VII, and to the description of the pipe under that number.

FORMULAS FOR FLOW OF WATER IN WOOD-STAVE PIPE.

Water is caused to flow and velocity created by the force of gravity. Thus the flow follows the general law of falling bodies, and the velocity tends to become constantly accelerated. This tendency is just balanced by the influences retarding the flow. For a pipe carrying flowing water under pressure, the difference in elevation, H_E

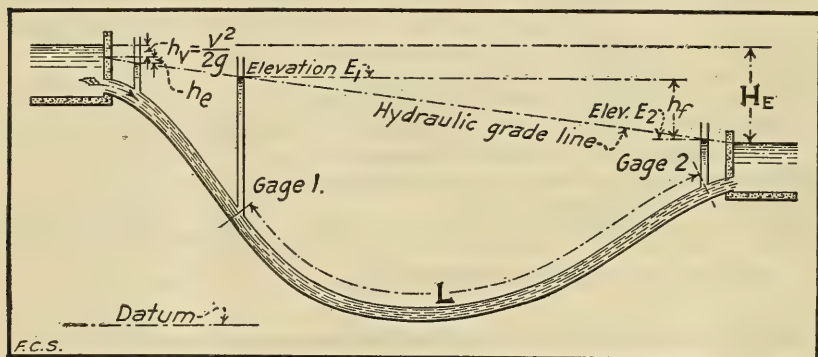


FIG. 1.—Hydraulic elements for loss of head in siphon pipe.

(fig. 1), between the surfaces of the water at the intake and outlet is the effective head through which the force of gravity acts. The effective or lost head is made up of several individual losses as follows (fig. 1):

$$\text{Velocity head} = h_v = \frac{V^2}{2g} \quad (1)$$

This is the head absorbed in creating the mean velocity V , at which the water is conveyed through the pipe. This loss occurs at the intake.

As a rule, little or none of this velocity head is recovered at the outlet of the pipe. The conditions under which recovery may be expected are discussed on page 61.

$$\text{Entry head, } h_e = \frac{h_v}{2} \text{ (approximately).} \quad (2)$$

The amount of loss at the entry, due to the effect of contraction eddies and other retarding influences, is variable and uncertain, but most authorities agree that it should be taken as half the velocity head unless the inlet structure is especially designed to minimize this loss. For further discussion see page 59.

Friction head, h_f , is that lost in overcoming the retarding influences within a reasonably straight pipe. In pipes of great length, the amount of this loss so far exceeds the two losses first mentioned that they may often be neglected, especially in small pipes. This is the loss upon which the experiments described in this paper were concentrated. Apart from all other losses of head it must be found in order to permit solution of the various formulas for the flow of water in pipes with the view to securing additional values for the factor representing the retarding influences designated as friction.

In addition to the above losses, there may be others, such as those due to bends and valves or other obstructions; but, as a general thing, these items do not enter the design of wood-stave pipes, especially for irrigation purposes. In this use the pipe is laid on such gentle curves, both horizontal and vertical, that such losses need not be considered. Valves are seldom set across the line of the pipe, although there are often one or more valves of various sizes leading from the pipe. The loss in the main line due to these valves is also negligible compared with the friction and velocity head losses.

In 1775, Chezy, a French engineer, offered his now well-known formula for the flow of water in both open channels and closed conduits:

$$V = C\sqrt{Rs}. \quad (3)$$

Here C is a coefficient, originally thought to be constant, but now known to vary with functions of the slope, the hydraulic radius, the velocity, and with some factor representing the retarding influences in the channel. Many of the formulas used in this country for the design of pipes have accepted the Chezy formula as a basis and made only such modifications as experience dictated, some of them merely assigning definite values to the coefficient C for definite conditions of velocity, roughness, and size of pipe.

Since the hydraulic elements secured in the field experiments furnish the necessary data for the determination of the factor representing the retarding influences in all the formulas most used in this country, this publication will show this factor as developed by field tests for several formulas as follows:

(a) The Chezy formula, 3 on page —,

$$V = C\sqrt{Rs} = CR^{0.5}s^{0.5} \quad (4)$$

(b) The Kutter modification of the Chezy formula,

$$V = \left\{ \frac{\frac{1.811}{n} + 41.66 + \frac{0.00281}{s}}{1 + \left(41.66 + \frac{0.00281}{s} \right) \frac{n}{\sqrt{R}}} \right\} \sqrt{Rs} \quad (5)$$

in which C is elaborated so that it takes into consideration the influence of the hydraulic grade and of the mean hydraulic radius and introduces a new variable, n , which is supposed to represent all the retarding influences.

(c) The Weisbach formula,

$$h_f = f \frac{LV^2}{2Dg} \quad (6)$$

From the same field data comparison is made between the following formulas:

(d) The Tutton¹ formula for flow in wood-stave pipes,

$$V = C_1 R^{0.66} S^{0.51} \text{ with } C_1 = 129 \quad (7)$$

C_1 in this formula is not to be confused with C in the Chezy formula.

(e) The Williams-Hazen general formula² for many kinds of pipes

$$V = C_w R^{0.63} S^{0.54} 0.001^{-0.04} \quad (8)$$

which may be arranged in the same form as formulas 9 and 12 for comparison, becoming, with $C_w = 120$,

$$H = \frac{.469 V^{1.852}}{D^{1.167}} \quad (8a)$$

For wood-stave pipe a value for C_w of 120 is recommended by Williams and Hazen. This recommendation is based on their study of pipes Nos. 20, 41, 44, 47, and 48, Tables 2 and 3. The exponents of the formula "were selected as representing as nearly as possible average conditions, as deduced from the best available records of experiments upon the flow of water in such pipes and channels as most frequently occur in waterworks practice."

(f) The Moritz formulas:³

$$H = \frac{8.6 V^{1.8}}{d^{1.26}} = \frac{0.38 V^{1.8}}{D^{1.26}} \quad (9)$$

$$V = 1.72 D^{0.7} H^{0.555} \quad (10)$$

$$Q = 1.35 D^{2.7} H^{0.555} \quad (11)$$

These three formulas express the same values from different points of view. Unlike formulas 4, 5, and 6, they were developed

¹ Tutton, C. H. Journal Assoc. Engin. Soc., 23 (1899), p. 151.

² Hydraulic Tables, Williams and Hazen, 2d ed. New York, 1909.

³ Flow of water in pipes, E. A. Moritz, Eng. Rec., 68, No. 24, p. 667.

from an extensive series of experiments on wood-stave pipe from 4 to 55 $\frac{3}{4}$ inches in diameter and were offered for use on wood-stave pipe only either jointed or continuous.¹

In the development of formulas 9, 10, and 11 Moritz used only his own experiments on the pipes as indicated on Plate VII, rejecting all prior tests by other experimenters.

(g) A new set of formulas is offered by the writer, based on all experiments on round stave pipe known to him from description in engineering literature, and supplemented by an extensive set of experiments in which he was aided by Ernest C. Fortier. The method used in developing these formulas is explained on page 50. Hereafter any one of this set of formulas will be referred to as the new formula. Arranged in the same order as the Moritz formulas for comparison:

$$H = \frac{7.68 V^{1.8}}{d^{1.17}} = \frac{0.419 V^{1.18}}{D^{1.17}} \quad (12)$$

$$V = 1.62 D^{0.65} H^{0.555} \quad (13)$$

$$Q = 1.272 D^{2.65} H^{0.555} \quad (14)$$

It is to be noted that the exponent of V in formulas 9 and 12 is the same, as is also the exponent of H in formulas 10-11 and 13-14. The difference in the formulas is caused by the wide divergence in the intercept curves shown in figure 4 (p. 56). As indicated in these curves, the difference becomes greater as the larger pipes are approached, for the reason that all weight for large pipes in the Moritz formulas came from his tests on the 55 $\frac{3}{4}$ -inch Mabton pressure pipe (Nos. 45 and 46), and the position of the points representing the intercepts for this pipe, in figure 4, indicates that this pipe was abnormally smooth.

Referring to formula 8a, it will be seen that the exponent of D in the new formula is almost identical with the exponent of D in the converted Williams-Hazen formula and that it follows the suggestion of Schoder:² "If the attempt is made to lump all pipes except the very smooth ones and the small tuberculated ones, giving thereby more weight to large rough pipes and ordinary lap-riveted pipes, then m will be found to vary inversely about as $D^{1.15}$ to $D^{1.20}$."

TREND OF ENGINEERING THOUGHT REGARDING THE CARRYING CAPACITY OF WOOD-STAVE PIPES.

The ideas of the engineering profession concerning the carrying capacity of wood pipe, expressed as direct statements or as formulas, have varied widely during the past 20 years. Wood-stave pipe enters into direct competition with iron and steel pipe. The claim

¹ For details of these experiments see Trans. Amer. Soc. Civ. Engin., 74 (1911), p. 411.

² Friction Head Hydraulics and Pipe Flow Diagrams, Ernest W. Schoder, Cornell Civil Engineer, May, 1910.

has persisted that there is less friction in wood pipe than in metal pipe. It has often been insisted that new wood pipe not only has a higher carrying capacity than new metal pipe but that the wood pipe becomes smoother with age, while it is a well-known fact that metal pipe becomes rougher. (See discussion, p. 72.)

While the analysis of all the tests on wood pipe now available bears out the above claims in a general way (excepting that wood pipe is not shown to become smoother with age), yet the consideration of tests on individual pipes led to hasty conclusions presently shown to be greatly at variance with facts. The following ideas of hydraulicians have been extracted by the writer from all the literature on the subject known to him:

The experiments of Darcy and Bazin in 1857 and 1859 (Nos. 22 and 33) and of Clarke in 1884 (No. 49) were considered but little in later discussions for the reason that they were made on rectangular rather than on round pipe. Smith's test (No. 1), made in 1877, has also not been considered in the discussion of wood pipe, as the test was made on a bored pipe of very small caliber; yet these four series supplied the data upon which Tutton based his formula. (See p. 50.)

Although none of the 81 tests considered by Kutter and his colleague in developing the Kutter formula had been made on closed channels running full, yet nearly all of the experimenters on wood-stave pipe have determined for their tests the value of n in this formula. Kutter's formula has undoubtedly been used a great deal in estimating the capacity of wood pipes, but the writer will endeavor to show (p. 56) the fallacy of employing a constant value of n in this formula and the advantages lying in a formula of the exponential type.

The first experiment of public record was mentioned by the late J. D. Schuyler¹ in speaking of a test (No. 34) on the newly installed 30-inch pipe for Denver, but unfortunately he did not give sufficient details by which the test might be weighed. Mr. Schuyler states that "as low a coefficient of n as 0.0096 can be used." This appeared reasonable, as the pipe was made of planed lumber and all lists of proper values of n then published recommended a value of 0.009 for such material. The earlier designers adopted a value of 0.010 "in order to be conservative."

The next tests were made by A. L. Adams² on the Astoria, Oreg., 18-inch pipe (No. 23). Here, too, a low value of n was found, 0.00985, which led Adams to observe "that the value of 0.010 for n used by many engineers in dealing with stave pipe, is here found to be practically correct." The low value of the friction factor found in this

¹ Trans. Amer. Soc. Civ. Engin., 31 (1894), p. 144.

² Trans. Amer. Soc. Civ. Engin., 36 (1896), p. 26.

test is the more remarkable in view of the fact that there are "in addition to a succession of sweeping horizontal and vertical curves, 27 cast-iron bends with a radius of curvature of 5 feet, and with an average central angle of about 31° ." (See Pl. XIV, fig. 1.)

The next test (No. 32), spoken of by F. B. Gutelius,¹ was conducted by D. C. Henney² on the Butte, Mont., 24-inch pipe in 1892. In this test the value of n was found to be 0.0103. Here again was a value so close to 0.010 that it tended to establish the fact that 0.010 was, closely, the proper value. After these three tests by three different experimenters an extensive series of tests would naturally be required to convince the profession that a higher value of n should be used. Attention may here be directed to the fact, however, that in the three last-mentioned tests but one or two runs of water, with little or no variation in velocity, had been observed.

In 1897 Profs. Marx, Wing, and Hoskins³ of Leland Stanford Junior University, made a careful and vastly more extensive series of tests than any previously carried through (No. 47). The values of n varied inconsistently between 0.010 and 0.0204. (See Table 2, column 10.) Of the 22 runs in this series, all but one showed a value of n above 0.0123, and most of them showed it above 0.013.

The experimenters did not publish their results as values of n , merely stating:⁴

In regard to the applicability of Kutter's formula it is to be said that the experiments on the wooden pipe herein described give values of n ranging from 0.012 to 0.015, an average value being perhaps 0.013. The difference between this value and those given for the Denver and Butte city conduits can hardly be attributed to the greater roughness of the Ogden pipe. It is rather to be supposed that the Kutter formula is defective. (See p. 56.)

In correspondence relating to these tests T. A. Noble offers the values of n for the various observations.⁵ These have been checked by the writer and are found in Table 2, column 10. In the same correspondence (p. 544) A. L. Adams offers his tests on the West Los Angeles pipe (No. 20) where the values of n range from 0.0105 to 0.0111. Mr. Adams voices the following warning:

These values * * * do not indicate 0.01 as being a safe assumed value for n as have all previous experiments.

Various arguments were brought forward to furnish a reason for the unprecedentedly high values of n in the Ogden pipe. These included the following: That Kutter's formula did not apply to pipes as large as 6 feet in diameter; that sediment had deposited in the pipe; that the nominal area was not the true area; that a constant reduction factor should not be used in computing the equivalent water column from the mercury column.

¹ Journal Assoc. Engin. Socs., 12 (1893), p. 219.

² Journal Assoc. Engin. Socs., 21 (1898), p. 250.

³ Trans. Amer. Soc. Civ. Engin., 40 (1898), p. 471.

⁴ Id., p. 516.

⁵ Id., p. 547.

In 1899 the same experimenters made additional tests (No. 48) upon the same pipe with improved apparatus.¹ Their experiments were centered on a longer reach of pipe and a consistent set of values of n was obtained, ranging from 0.0130 to 0.0133.

The trend of the discussion of the second Ogden tests shows that a general belief existed to the effect that the difference in the values of n , when compared with n for smaller pipes, was due to defects in the Kutter formula.

A graphic presentation of the data then available was made on ordinary squared cross-section paper. In the discussion a method was offered for testing the correctness of experimental data by the use of this paper, "if the loss of head varies as the square of the velocity."² Although as long ago as 1808, Dr. Thomas Young³ suggested that the loss of head was in proportion to the 1.8 power of the velocity, rather than the second power, many still insisted that loss of head must vary as the square of the velocity. It is interesting to note that 1.8 is the exact exponent found by both Moritz and the writer, while Williams and Hazen use an exponent of 1.85 in their general formula for flow in many kinds of pipes.

In 1901 T. A. Noble⁴ contributed greatly to the available knowledge by making tests on 44½-inch and 54-inch pipes (Nos. 41 and 44), thus bridging the gap between 30-inch and 72-inch pipes. For both these pipes the values of n ranged from 0.0120 to 0.0136, with the higher values in the smaller pipe, although the same water flowed through both pipes and they were constructed at the same time. Also, strange to say, the pipe with the lower value of n contained more curvature and growths of *Spongilla* which were not present in the smaller pipe. Noble says:⁵

The writer can offer no suggestion as to why the value of C should be less and n greater in the 44-inch than in the 54-inch pipe, when, to conform to the results of other experiments, it should be the reverse.

In discussing the available data on this subject,⁶ E. W. Schoder of Cornell University suggests the possibilities of an exponential formula derived from a study of the straight-line curves resulting when the losses of head are platted on logarithmic paper as ordinates and the velocities as abscissas. This was the method used later by Moritz in deriving his formula, and also by the writer as being the best known form by which to study the now extensive number of tests upon wood pipe.

¹ Trans. Amer. Soc. Civ. Engin., 44 (1900), p. 34.

² Id., p. 73.

³ Philosophical Trans., Royal Society of London (1808).

⁴ Trans. Amer. Soc. Civ. Engin., 49 (1902), p. 112.

⁵ Id., p. 143.

⁶ Id., p. 145.

Gardner S. Williams¹ says:

One of the most interesting features of the investigation is the light it throws upon the inapplicability of the long-honored law that loss of head varies as the square of the velocity.

He offers the deductions, based on the study of more than 80 series of tests by 13 observers, that the exponent increases from 1.80 to 2 in pipes ordinarily used by engineers; that it increases as the roughness increases; that it decreases as curvature increases, and that it is different for different materials, being lowest for tin and brass.

After the Noble tests nothing was offered in engineering literature until J. L. Campbell² made tests on the El Paso & Southwestern Railway pipe (Nos. 15 and 21). The values of n were so low that the results were seized upon by some wood pipe manufacturers and given out broadcast as the values of n to apply to wood pipe. These values showed an enormously greater carrying capacity for wood than for iron or steel pipe. The results are unquestionably too low for the following reasons: In the discussion G. E. P. Smith³ asks, "Was the first appearance or the average time of appearance, accepted for computing the velocity of flow?" to which Campbell replies (p. 188), "Referring to Mr. Smith's question about the velocity measurements by bran, the *first* appearance of the bran and the colors was taken because the intervals of time given thereby were in close accord among themselves and with the weir measurements." (*Italics are the writer's.*)

In the opinion of the writer, who used color for many of his experiments (see p. 23), the mean of the first and last appearance of color comes quite close to the true mean. (See also the article by E. W. Schoder in the Cornell Civil Engineer, December, 1911.) If the first indication of color is taken, then the maximum thread of velocity is used; or, if diffusion in addition to mechanical mixing occurs, a velocity in excess of the true maximum is indicated. No one would suggest accepting as the average the velocity of a float down the maximum current in an open channel without applying a coefficient which varies from about 0.55 to 0.95. The fact mentioned by Mr. Campbell, that the "intervals * * * were in close accord among themselves," proves nothing but consistency. Regarding the agreement with the weir it should be remembered that this device gives discharge; color and bran tests give velocity. To permit comparison with the results of weir tests the velocity must be multiplied by the area of the bore. If the velocity as determined by the colors were taken too high and the assumed area of the bore too low,

¹ Trans. Amer. Soc. Civ. Engin., 49 (1902), p. 155.

² Engin. News, 60 (1908), p. 225. Trans. Amer. Soc. Civ. Engin., 70 (1910), p. 178.

³ Trans. Amer. Soc. Engin., 70, p. 186.

the results might still agree with a weir test quite closely and yet include an error as to the velocity.

The writer dwells on this discussion for the reason that he has before him three catalogues of prominent pipe makers, each of which claims a very high efficiency for wood pipe (to the consequent disparagement of iron and steel pipe), basing this claim on one questionable series of tests and ignoring the other tests mentioned above for the probable reason that the most of the latter show the capacities of wood and new iron pipe to be more nearly the same.

In 1911 E. A. Moritz¹ offered the results of experiments which were quite complete between pipes 4 inches and 22 inches in diameter, with a gap then to one pipe 55 $\frac{3}{4}$ inches in diameter. He used much the same methods (in fact, much of the same equipment) which were used on the Ogden tests.

Rejecting all previous experiments and his own series on the 22-inch pipe (No. 28), Moritz developed the formulas given on page 6. This left a very complete set of experiments between 4 and 18 inches but with a gap from 18 to 55 $\frac{3}{4}$ inches. The positions of platted points for the 55 $\frac{3}{4}$ -inch pipe (Nos. 45 and 46) shown on Plates VI and VII, when compared with corresponding points for other pipes, all indicate that this pipe was exceptionally smooth. So much weight was given the tests on this pipe, being the only tests on large pipe which were accepted, that the formulas derived from the experiments indicate a greater carrying capacity for wood pipe generally and large diameter wood pipe particularly than a study of all tests shows to be warranted.

In the discussion of Moritz's article, R. G. Dieck writes:

The use of the Kutter formula in pipe design has always been questionable, even though its ease of application, in default of a more convenient formula, has commended it * * *. It is evident from the Sunnyside experiments that an adjustment in the ideas of hydraulicians on this point is bound to come. * * * When the discharge varies, all other conditions being the same, the value of n also varies; hence in its present form, the Kutter formula can not be considered a true statement of conditions.²

In the same discussion³ Rudolph Hering states that he "recognized as well as did Mr. Kutter himself, almost at the outset, that n was not to be considered a precise and unvarying constant." The writer will take up the comparison between the Kutter and the new exponential formula later (p. 56).

In the same discussion Gardner S. Williams objects to the inconsistency of the profession in introducing inches into a formula otherwise expressed in feet and decimals. The writer agrees in this, but the manufacture of iron, steel, clay, and wood pipe has been so long

¹ Trans. Amer. Soc. Civ. Engin., 74 (1911), p. 411.

² Id., p. 452.

³ Id., p. 459.

conducted on these units that it appears best to construct separate formulas with terms in both inches and feet.

Also in the same discussion¹ J. S. Moore, who aided in the experiments and computation of the Moritz data, offers tests on 48 $\frac{3}{4}$ and 31-inch pipes (Nos. 43 and 36). The 48 $\frac{3}{4}$ -inch pipe appears to have been very smooth and the tests confirm the Moritz formulas. However, it must be borne in mind that this pipe is part of the same siphon and subject to the same conditions as those affecting the 55 $\frac{3}{4}$ -inch pipe which contributed so largely to the data from which the Moritz formulas were derived. Advocating the use of all previous data accepted as criteria, Moore suggests the intercept line for the exponential formula as shown by the dash line in figure 4. This line approaches the position of the intercept line for the new formula which considers all reliable data.

RECAPITULATION.

The above outline indicates that 25 years ago Kutter's formula, with a value of n of 0.010, was accepted as accurate in the design of wood pipes. As tests were made on larger sizes of pipe, higher values of n were found. These results were not accepted unreservedly, however; rather were the experiments discredited by some designers on the grounds that conditions in the pipes were not properly ascertained or that methods of making observations were erroneous. The experimenters themselves suggest that perhaps a constant value of n should not be used; that is, that Kutter's formula does not apply if a constant value of n is to be taken. The data were too meager to develop the variation in n with the diverse elements.

As data accumulated authorities suggested interpreting results by exponential formulas; but not being well known this method was not extensively accepted until used by Moritz in interpreting his own results. He attempted to compare his formulas with the results of other experimenters but found this "a difficult and discouraging problem." This was true because all previous data on large pipes showed a much smaller relative capacity than the *one* pipe contributing so largely to his formulas. Though but tentatively offered by Moritz, his formulas appeared to be the best available and have been extensively accepted, in spite of the fact that Moore, who was perfectly familiar with the Moritz tests, suggests a formula that more nearly fits all previous observations.

In the following pages of this publication, particularly beginning on page 28, the writer will endeavor to show analytically the following:

1. That an exponential formula most nearly applies to the flow of water in wood-stave pipes.

¹ Trans. Amer. Soc. Civ. Engin., 74 (1911), p. 463.

2. That the mean of all reliable observations on carrying capacity of wood-stave pipes agrees with the exponential formulas in the following order and per cent (see Table 2):

	Per cent.
1. Scobey.....	-0.33
2. Williams-Hazen ¹	+2.41
3. Tutton.....	+2.44
4. Moritz.....	-9.40

3. That the mean of the capacities of the several pipes agrees with the exponential formulas in the following order and per cent (see Table 3):

	Per cent.
1. Scobey.....	+0.66
2. Williams-Hazen.....	+3.51
3. Tutton.....	+5.02
4. Moritz.....	-7.64

4. That Kutter's formula with a constant value of n does not apply to flow in wood-stave pipes running full.

5. That n decreases with an increase in velocity in a given size of pipe and increases with the size of pipe for a given velocity, varying from less than 0.010 for small pipes at high velocities to more than 0.014 in large pipes.

6. That this variation in n is so marked and complicated as to render the use of Kutter's formula inadvisable.

7. That the Ogden experiments showed the capacity of the 72-inch pipe (Nos. 47 and 48) to be within from 5 to 8 per cent of the average.

8. That the Sunnyside experiments showed the 55 $\frac{3}{4}$ -inch pipe (Nos. 45 and 46) to be abnormally smooth by 18 per cent.

NECESSARY FIELD DATA FOR DETERMINING THE RETARDATION ELEMENTS OF VARIOUS FORMULAS.

A glance at pages 5 to 7 shows that for study of the various formulas the same hydraulic elements must be determined by field tests. These are:

1. The mean velocity, V , of water in the pipe.
2. The loss of head, h_f , due to retardation in a section of pipe of uniform size, within a known distance.
3. The internal size of pipe, D or d .

The above data having been secured, the observed velocity for any particular observation may be compared with the computed velocity for the same-sized pipe with the observed loss of head, for any of the formulas.

MEAN VELOCITY OF WATER.

The velocity of the water flowing in a section of wood-stave pipe may be measured in two general ways:

¹ Using coefficient of 120 in Williams-Hazen formula.

1. Directly, by timing a given volume of water through a known distance.

2. Indirectly, by measuring the discharge of the pipe, thus determining the quantity, Q , and solving the equation $V = \frac{Q}{A}$.

Where the velocity is tested by the direct method the error is smaller than where the indirect method is used.

LOSS OF HEAD DUE TO RETARDATION.

Most of the recent experiments on the flow of water in pipes of uniform size have been made with piezometer columns. This was the method used by the writer. If a piezometer (fig. 1) be properly attached to the pipe, the pressure in the latter will support a column of water whose surface is at elevation E_1 on the hydraulic grade line. In the same way the pressure at gauge No. 2 will lift a column to elevation E_2 . The difference between these elevations is the head lost, h_f , due to the retarding influences.

INTERNAL SIZE OF PIPE.

It was not practicable to secure inside measurements of any of the pipe tested in the experiments conducted by the writer. The method used in ascertaining the inside cross-sectional area of the pipe is recounted in the description of each test. In some cases several joints of pipe, remaining from construction, were measured and their mean inside cross-sectional areas accepted as the internal sizes of the operated pipes. In other cases the external circumferences of the reaches tested were measured in several places and the mean inside cross-sectional areas computed, the thickness of the staves being known. This thickness runs very uniformly, being determined at time of manufacture by the use of the same templet.

In still other cases, especially on pipes of small diameter, the nominal diameter of the pipe was accepted. As the pipe runs very close to nominal size the writer believes that no appreciable error is introduced in accepting these areas, provided the conditions are such that the pipe is not liable to be more or less clogged with rocks, sand, or other débris.

SCOPE OF THE EXPERIMENTS.

The writer conducted 64 tests on 16 separate pipes, 13 of which ranged from 8 inches to 4 feet in diameter; one was $6\frac{1}{2}$ feet; one, 12 feet; and one, $13\frac{1}{2}$ feet in diameter. Six pipes were of the machine-banded type, put together in lengths, and 10 were of the continuous-stave type. Mean velocities ranged from less than 1 foot per second to more than 8 feet per second.

From other sources, listed in summary Table 3, and briefly described in the appendix commencing on page 74, descriptions of experiments

on pipes up to 6 feet in diameter were abstracted, but no other than the writer's records are available for pipes between 6 and 12 feet in diameter.

EQUIPMENT AND METHODS EMPLOYED FOR COLLECTING AND INTERPRETING FIELD DATA.

In order to correctly weigh any new data bearing on hydraulic formulas it is necessary to know in detail the equipment used and the steps pursued in both the field and office. Consequently these features are described in some detail.

EQUIPMENT.

Tapes.—High-grade steel tapes, graduated in feet and hundredths, were used in the determination of diameters, circumferences, etc. For distance chaining the tape was graduated to tenths.

Level.—An 18-inch Berger engineer's wye level, equipped with a bubble whose sensibility was rated at 10 seconds of arc for 1 division of scale equal to one-tenth of an inch was used. The bubble vial was 6.5 inches long; the telescope power was 35 diameters. The instrument was kept in excellent adjustment.

With one exception the levels in these tests were closed within the limits suggested by the U. S. Geological Survey, the allowable error in feet being $0.017 \sqrt{\text{distance in miles}}$.¹ The exception noted occurred in connection with the tests on pipe No. 37, where the levels were run in high wind, over deep sand. Several trials were made, but the best closure was to 0.023 foot, while to conform to the formula it should have been to 0.012 foot, the distance being about 2,500 feet.

Rod.—A new Philadelphia rod, in three sections, equipped with rod level and vernier reading to thousandths of a foot was used in the determination of the elevations of gauge zeros with regard to an assumed datum.

Thermometers.—Temperatures of air and water were taken with all-glass laboratory thermometers, graduated to degrees and fifths, Centigrade scale. The range covered in the graduations was only that liable to be encountered in the tests, so that each degree was represented by about three-sixteenths inch.

Hydrometer.—Specific gravity of water in the pipes was tested by means of a laboratory hydrometer simultaneously with a like determination of the temperature of the water. The hydrometer was afterwards tested by the U. S. Bureau of Standards. The proper corrections were thereafter applied to readings before computation was undertaken.

Current meter.—A small Price cup current meter of the combination type was used. This meter had been carefully rated by the U. S.

¹ Precise Leveling, in Topographic Instructions of the U. S. Geological Survey, 1913, p. 100.

Bureau of Standards the year previous, but had been used only a few times, and then as a standard. Its rating curve was checked by the writer and his assistant in the channel of the hydraulic laboratory at Cornell University, just prior to these tests. No change was found necessary.

*Fluorescein.*¹—Direct measurements of velocity of water in a pipe were made by injecting solutions of fluorescein and timing the passage of the resultant green-colored water through the reach tested.

Weirs.—Where weirs had been installed to measure the quantity of water from pipes the writer made use of them. Each is described in the report of the test in which it was used.

Hook gauge.—A small hook gauge of the Boyden type, with vernier reading to thousandths of a foot, was used to determine surface fluctuations for head on a weir. (See Pl. 1, fig. 1.)

Piezometers.—Two types were used:

Water column: This was employed where the pressure in the pipe was low. A simple glass manometer-tube, engine-divided to tenths and hundredths of a foot, was connected to the tap in the wood pipe by a piece of rubber pressure tubing. (See Pl. II, fig. 1.)

Mercury manometer: Where otherwise the pressure would have compelled the use of a long water column, a mercury manometer of the U-tube pattern was selected. Two of these U-tube mercury gauges, as shown in figure 3, were provided. They consisted of wrought-iron U tubes with unequal legs. The short leg was a glass manometer tube surmounted by a tee connection provided with the necessary cocks for manipulation. The long leg was formed of 2-foot units of one-eighth inch wrought-iron pipe until a length had been attained which permitted the top of the high mercury column to show in another glass tube.

These glass tubes were engine-divided into tenths and hundredths of a foot, the tenths and half-tenths lines extending completely around the tube and the other lines but half way around. By sighting through the tube across the front and back of any one line, all tendency toward parallax was removed and the mercury column could be correctly read to thousandths of a foot. The relative vertical positions of the two sets of graduations were of immaterial consequence as the graduations on each gauge glass were brought into the general scheme of levels above an assumed datum, as shown in figure 2.

All abutting pipes screwed against fiber gaskets. The ends of the gauge glasses were permanently set into sleeved couplings with sealing

¹ The writer is indebted to R. B. Dole, of the U. S. Geological Survey, for suggesting the use of this wonderful coloring matter. See "Use of Fluorescein in the study of underground waters," R. B. Dole, Water Supply Paper No. 160, U. S. Geological Survey.

wax. Both the couplings and attendant follow nuts were recessed at an angle of 45° in order to effectively bind rubber gaskets. Joints between ends of iron pipe units were made in the same way. A cement made of equal parts of beeswax and turpentine softened the rubber gaskets and gummed the pipe threads so that the joints were mercury-tight. This was doubly assured by winding sewing thread into the wax in the pipe threads.

The inside of all metal pipes and connections was japanned three coats thick in order to prevent amalgamation with the mercury.

Color injector.—The only practicable method of measuring the velocity of water in some of the pipes tested was by timing the passage of some color or chemical. After various tests fluorescein appeared to offer the best results. In order to inject the color into the pipe at

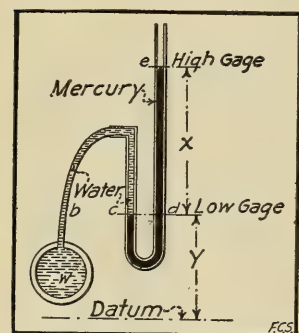


FIG. 2.—Hydraulic principles of mercury manometer of U-tube type.

the upstream gauge the "fluorescein gun" was developed (fig. 3). This is connected to the nipple C through the T connection D. At the downstream manometer the nipple C connects directly to the cock E.

Mercury container.—The usual lead torpedo weights for the current meter were dispensed with and a combination mercury bottle and meter weight was constructed (fig. 3). The details are evident in the illustration with the possible exception of the surge walls which divided the bottle into small compartments so that the

mercury gave no trouble by surging when the bottle was used as a meter weight. Likewise the small holes in the walls at the top of the weight offered small chance of losing all the mercury in case of accident.

FIELD METHODS.

CHOOSING A REACH TO BE TESTED.

In order to be considered adaptable for field tests, a pipe must be practically water-tight (or the leaks measured) and of such length, without bends or obstructions, that the effect of errors is minimized—the longer the better. Gentle curves, both vertical and horizontal, were thought desirable, as their effect must be considered in the design of practically all wood-stave pipes. No distinct bend in any pipe was included in the reaches tested. Such a bend would cause an appreciable loss of head aside from friction loss. Some method of determining the mean velocity in the pipe must be available.

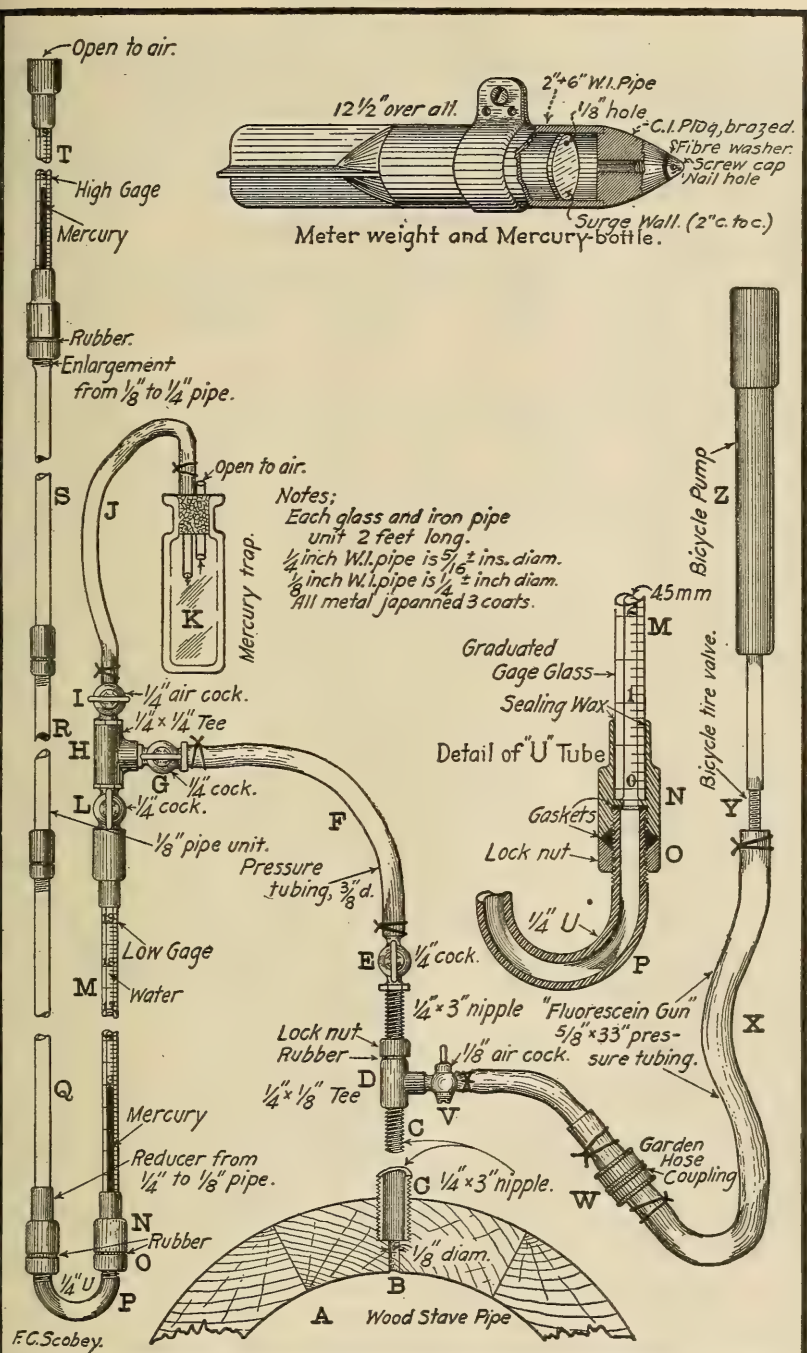


FIG. 3.—Method of attaching mercury manometers to wood-stave pipes. Details of menometers, fluorescein gun, and combined current meter weight and mercury bottle.

ATTACHMENT OF PIEZOMETERS.

As it is not often practicable to secure permission to make several holes at each manometer in a wood pipe used commercially, the writer accepted the discussion of Profs. Marx, Wing, and Hoskins concerning the position of the point of attachment to the pipe and whether different results will be given by multiple attachment than by attachment at a single point.¹ Their first conclusion is:

When the pressure in the given cross section of the pipe everywhere exceeds that of the atmosphere an open piezometer will stand at the same height at whatever point of the cross section it be attached, and whether it communicates with the pipe at one point or at several.

As a rule taps were not made on the top of the pipe, as the writer judged that more air bubbles would be in the water at this part of the pipe than at some lower point. Care was exercised in choosing the reach, so that gauges could be set at each end of it, where the positions of the two taps would be such that the same relationship to velocity would hold. All taps were made on tangents. The position on the circumference was chosen in the neutral zone where the influence of curves would be a minimum. For instance, if the pipe was straight in horizontal alignment, but curved vertically, the taps were made in the side of the pipe. In experiments on pipe No. 52, where the pipe followed a chosen gradient but was curved horizontally, taps were made near the top of the pipe. (Pl. V, fig. 3.)

The essential requirement in a piezometer connection is to exclude all positive or negative influence of velocity head. The hole through the pipe must be normal to the pipe and as clean cut as possible on the inside. If splinters are pushed off the inner surface, then either positive or negative influence from the velocity head must act on the column in the gauge, whereas the pressure head alone is desired.

The gauges were attached to the pipe in a manner slightly modified from that used by Noble² and later by Moritz.³ They bored a hole for the nipple with a wood bit until the tip of the bit pierced the inner surface. In the experiments described in this paper a seven-sixteenth-inch wood bit was used to make a hole about 1 inch deep. Then a twist drill one-eighth inch in diameter was twisted by hand until the inner surface of the pipe was cleanly pierced (fig. 3). Experiments made with both systems showed the holes made by the last method to be more nearly free from splinters which might affect the gauge tube by velocity head.

¹ Trans. Amer. Soc. Civ. Engin., 40 (1898), p. 526.

² Id., 49 (1902), p. 119.

³ Id., 74 (1911), p. 411.

OPERATION OF GAUGES.

From observations on the ground or study of the profile, the pressure in the pipe was known roughly. In assembling the gauge the proper number of iron-pipe units was installed in the long leg of the U so that the two ends of the mercury column balancing the pressure in the pipe would appear near the mid-point of the glass gauge tubes.

The gauge, as assembled in figure 3, was set up beside the tapped pipe, the glass tubes being made truly vertical by means of a plumb bob. Shade was always provided for the gauges.

With the cocks I and L open and G closed, mercury was filtered into the tube T. A paper-lined glass funnel was inserted at the top of T. The mercury filtering through a pin hole at the bottom of the paper funnel was thus cleansed at each experiment and the meniscus in each tube was made bright and clear. Mercury filtered into a tube of small diameter in this manner will fill up without air bubbles, but if it is poured into such a tube air bubbles will occupy long reaches of pipe and may not be found if they occur in the iron-pipe sections. When both legs of the gauge were filled to near the top of the lower glass, I was closed and G opened until the mercury column in M was pressed well down in the gauge, when G was again closed. Mercury was then added and G was opened from time to time until it might be allowed to remain open, the pressure holding the mercury column in sight on both glass gauge legs.

At this time there was probably a mixture of air and water above the mercury in M, but the air was driven out by alternately closing G and opening I for an instant. In using the gauges L was closed and G and I opened every few minutes, so that water and any accumulated air bubbles might be blown out of the pressure tube between the gauge and the wood pipe.

Because of the use of unequal legs on the gauge there was danger of blowing mercury out of the gauge at I unless the cocks L and G were operated most carefully. To catch the mercury in the event of such an accident, the tube J was discharged into the bottle K which included a glass tube open to the air so that water was freely discharged but the mercury caught.

Pulsations were nearly always present and as simultaneous readings of both low and high gauges were necessary in order to determine the length of the mercury column, readings were made in the following manner:

Pulsation effect was reduced by partially closing either L or G until the mercury was barely "alive." This assured an average length of column. The cock was then completely closed, leaving a "dead" mercury column of the proper length. Both low and high gauges were carefully read to thousandths after which the cock was

opened. This process was repeated every 10 minutes. All other readings were taken by alternately reading high and low gauges with the mercury just alive, the corresponding reading for the other gauge being computed from the dead readings as described above. Since the only change in the total length of mercury thread was due to temperature changes, and since the gauges, which were made of the highest grade of manometer tubing, were practically uniform in diameter, no error was introduced by reading but one leg at a time, alternately. (See p. 93.)

DETERMINATION OF LOST HEAD.

The exact amount of h_r (fig. 1) must be determined. Where a water column is used, say at gauge No. 2, the elevation E_2 is the gauge reading added to the elevation of the gauge zero above an assumed datum, with proper corrections (see p. 23). Where a mercury manometer of the U-tube pattern is used, the reasoning is as follows: It is desired to know the elevation E_1 (fig. 1) for a water column which is the equivalent of a mercury column in a U-tube placed as for gauge No. 1. Referring to figure 2, the mercury in the two legs of the U-tube below c-d will be seen to balance. Therefore the pressure of the water at c is just balanced by the column of mercury X. But the pressure at c equals that at d. If the mercury X were replaced with water it would reach an elevation sX above d, where s is the specific gravity of the particular mercury in the gauge, compared with the particular water in the pipe. But the elevation to which this water column would reach is the desired elevation, E_1 . Therefore the elevation $E_1 = sX + y$ above the assumed datum. As applied to these experiments, referring to figures 1 and 2, the difference in elevation between the readings of the low gauge and the high gauge multiplied by the specific gravity of the mercury and added to the elevation of the low-gauge reading gave the elevation of the equivalent water column when the proper corrections had been applied.

CORRECTIONS.

Although quite numerous, the principles involved in all of the necessary corrections have been the subjects of such thorough investigation that appreciable errors are not liable to result from their use.

Temperature.—Corrections are necessary for the temperature changes in both air and water. A temperature of 15°C . was adopted as standard and the specific gravity of the mercury used in the tests was referred to that temperature, being compared to distilled water at the same temperature.

The mercury column balances the pressure of the water in the pipe, but this water may be either heavier or lighter than distilled

water. Hydrometer tests of the water at the time of the experiment showed the specific gravity of the water for that temperature. A table was computed showing the proper specific gravity factor to apply to convert the mercury column to the equivalent water column for any observed specific gravity of water.¹ No additional correction is necessary for the temperature of the water as the hydrometer takes this into consideration.

The pressure in the pipe (fig. 2) supports the mercury column X and in addition the water column from the pipe to the elevation of c. If this water is of a different temperature from that in the pipe a correction is necessary, but in these experiments the water was kept at about the same temperature by frequently blowing off the water in the rubber pressure tube. The length of this water column in a mercury gauge at no time was more than 1 or 2 feet.

However, in a water column manometer the difference in temperature must be considered. The temperature of the water in the tube was taken as that of the air adjoining, while the temperature of the water in the pipe was determined at the same time that its specific gravity was tested. Water columns were not blown off but air bubbles were driven to the glass tube by striking the rubber tubing sharply with a stick. Siphons in the pressure tubing were carefully prevented.

Capillarity.—Water rises by capillarity in a small tube and mercury is depressed. Two sets of glass tubes were used for water columns. For one, with inside diameter of 4.5 mm., water rises 0.017 foot, while in the other set, with diameter of 5.6 mm., the water rises 0.01 foot.

MEASUREMENT OF MEAN VELOCITY.

As a rule, each pipe tested presented its own problem as to the method to be adopted to determine the mean velocity of the water, and in case this method digressed from one of the following standard methods it is described.

Current meter.—Where the water entered or left the pipe in an open channel the discharge was determined with a current meter, and the velocity in the pipe was secured by dividing this discharge by the area of the pipe. The two-tenths and eight-tenths depth method was used, as the results obtained in this way, when compared with the discharge found by the multiple-point method, generally agree with it to about 1 per cent.

Fluorescein.—About 1 teaspoonful of fluorescein (in the form of red powder) dissolved in about a pint of water gave sufficient solution

¹ The mercury used in experiments conducted by the writer was tested for specific gravity in the laboratory of Nutrition Investigations, U. S. Department of Agriculture. The specific gravity was found to be 13.575 at 15° C., compared with distilled water at 15° C. These were the temperatures adopted as basic for the computation of results.

for four injections of color in a pipe carrying up to 60 second-feet, while in the 13½-foot pipe (No. 52) the total contents of the "fluorescein gun" (fig. 3) were injected at one time, and for the volume of water carried in this pipe (the maximum was 871 second-feet) a saturate solution was used. Though not measured, this consisted of about 4 teaspoonsful of the powder for each "shot" of about one-third pint. The powder dissolved readily in cold water.

In making a test the coupling W is opened and the solution poured into the pressure tube X. The gun is again connected with the apparatus by the coupling W. With E closed V is opened. Pressure in the wood pipe enters the gun, making pressures in both gun and pipe equal. In order to inject the color into the pipe the only thing necessary is to increase the now existing pressure in the gun. After V has been closed the gun is pumped up like a bicycle tire. While noting the time to a second the operator opens the cock V. By the hissing sound, it is probable that the jet passes well across the diameter of a medium-sized pipe. If the contents of the gun are to cover three or four injections V is opened and almost immediately closed. If all the contents are to be used a few quick strokes of the pump, after V has been opened, will clear the gun in a very few seconds, the mean time being accepted in later computations.

The observer at the outlet, provided with a watch agreeing to the second with that used in timing the start of the color, notes to the second the first and last appearance of the color. The color is extended by the variation in the velocity throughout the section of the pipe. This extension covers about 8 per cent of the total time the color spends in the pipe. Comparison with carefully constructed weirs shows that the color method is correct within about 3 per cent. Wherever possible, a comparison between color and current meter was also made. To secure comparative results the time the color spent in the pipe is taken as from the moment of injection to the mean between first and last sight at the outlet. These comparative tests are shown in Table 1.

TABLE 1.—*Velocities by color (fluorescein) compared with velocities by weir and current meter.*

Reference No.	Pipe diameter.	Crest length of weir.	Meter method.	Velocity per second by color. V_c	Velocity per second by meter. V_m	Velocity per second by weir. V_w	$\frac{V_c - V_m}{V_c}$	$\frac{V_c - V_w}{V_c}$
	<i>Inches.</i>	<i>Feet.</i>		<i>Feet.</i>	<i>Feet.</i>	<i>Feet.</i>	<i>Per cent.</i>	<i>Per cent.</i>
60	8	1.05 Cip. ¹	.....	1.251	.....	1.295	.....	-3.8
61	8	do.	.....	1.736	.....	1.735	.....	+0.1
62	8	2.84 Rect. ²	.....	2.048	.....	2.09	.....	-2.0
63	8	do.	.....	3.043	.....	2.97	.....	+2.4
64	8	do.	.....	3.294	.....	3.37	.....	-2.4
132	18	.....	6-tenths ³	2.08	1.99	.....	+4.3	.....
(4)	36	10.0 Cip. ¹	Int. ⁵	3.48	3.48	3.47	0.0	+0.3
(6)	36	do.	6-tenths ³	3.48	3.55	3.47	-2.0	+0.3
192	48	.....	2+8 ⁷	3.14	3.05	.....	+2.9	.....
193	48	.....	do.	3.75	3.71	.....	+1.1	.....
194	48	.....	do.	4.75	4.73	.....	+0.4	.....
263	78	Curve ⁸	.....	0.911	0.928	.....	-1.9	.....
264	78	do.	.....	0.963	0.974	.....	-1.1	.....
265	78	do.	.....	1.51	1.60	.....	-6.0	.....
266	78	do.	.....	2.063	2.08	.....	-1.0	.....
(5)	78	do.	.....	2.16	2.10	.....	+2.8	.....
269	78	do.	.....	2.40	2.37	.....	+1.2	.....
270	78	do.	.....	2.44	2.42	.....	+0.8	.....
271	78	do.	.....	2.79	2.51	.....	+3.1	.....

¹ Cipolletti weir with good conditions of contraction and velocity. See p. 40.² Rectangular weir with end contractions and sharp crest. See p. 40.³ Meter held in each vertical at 0.6 depth from surface.⁴ From tests on a concrete pipe, made in 1915.⁵ Velocity integrated by moving meter slowly from top to bottom and return.⁶ Excluded from Table 2 because gauge data lost for manometer No. 1.⁷ Meter held at 0.2 and 0.8 depths in each vertical; mean accepted for vertical. See p. 44.⁸ Rating curve developed by meter measurements. Velocity taken from curve. See p. 45

FIELD PROCEDURE.

After the reach of pipe was selected, the manometers attached, and other equipment put in readiness the method for proceeding with the field test was in general carried out as described in the paragraphs following. Any necessary changes are noted in the text in connection with the description of the individual pipes tested.

The watches used at both ends of the reach were adjusted to agree to the second, and again compared at the end of the observation. Manometers were read every one or two minutes (depending on the amount of pulsation in the water) for a period of 30 minutes. If a weir was used to measure the discharge of water a hook gauge above the weir was read every two to five minutes, depending on the variation of discharge. If a current meter measurement was necessary to determine the discharge it was made either during or immediately following the series of manometer readings, the manometers being watched for appreciable variations of discharge. Where fluorescein was used to time the actual velocity of the water it was injected into the pipe at approximately known intervals, say, five minutes, throughout the time during which the manometers were read. Ordinarily the second gauge was near enough to the outlet of the pipe so that one observer could both read the manometer and watch for the appearance of the color. Sometimes a third observer was necessary.

OFFICE EQUIPMENT AND METHODS.

Original multiplication, division, and addition were performed on mechanical devices. Checking was done by 20-inch slide rules and graphic methods. All percentage comparisons were made on 20-inch slide rules. Estimate diagrams were checked by proving random examples.

Office procedure.—Where water columns were used at both ends of the reach of pipe tested the loss of head in the pipe for the given velocity was the difference in elevation between the top of the mean water column at gauge No. 1 and the top of the mean column at gauge No. 2. Where a mercury manometer was used at one or both of the gauges the equivalent water column for each reading of the mercury column was computed. The mean of the elevations of the tops of the equivalent water columns was accepted as the elevation for that gauge. The loss of head was then computed as before. Standard methods were employed in computing current meter data or weir discharge. Where color was used in timing the velocity of the water the time was computed as from the instant of injection to the mean between first sight and last appearance of the color at the outlet.

ELEMENTS OF FIELD TESTS TO DETERMINE FRICTION LOSSES AND COMPARISON OF OBSERVED VELOCITIES WITH VELOCITIES COMPUTED FROM VARIOUS FORMULAS.

In the following pages two tables are arranged (Tables 2 and 3). Table 2 gives the elements of nearly all known observations on wood pipes, either round or square. The various series are arranged in ascending sizes of pipe and within one series the observations are arranged in ascending order of velocities.

The tests of one experimenter are omitted from these tables as extraordinary friction values were found. The writer made an independent set of tests upon some of the same pipes and found them so choked with ravelings from the rock cuts above the siphons that erroneous values were obtained. In the omitted tests the error lay in making current meter measurements for Q and then accepting $V = \frac{Q}{A}$ where A was taken as the nominal area of the pipe when as a matter of fact the true value of A was about 90 per cent of the nominal A ; therefore the true velocity was much higher than that found by the erroneous assumption of A .

EXPLANATORY NOTES ON TABLE 2.

Column 1 gives the consecutive numbers of the pipes as followed in column 1, Table 3, also in the discussions in the following pages and in the appendix. The small letter a after the numbers refers to discussion in the appendix. Experiments conducted by this department are discussed in the text while the essential data secured from other sources are abstracted in the appendix.

Column 2 gives a consecutive reference number to each observation.

Column 3 shows the authority (see also column 3, Table 3), the series number where such was carried, together with the date of the test.

HS refers to Hamilton Smith.

EM refers to E. A. Moritz, engineer of the United States Reclamation Service.

C refers to J. L. Campbell.

A refers to the late A. L. Adams.

DB refers to Darcy and Bazin.

H refers to D. C. Henny.

JDS refers to the late J. D. Schuyler.

JM refers to J. S. Moore, assistant engineer, United States Reclamation Service.

N refers to T. A. Noble.

MWH refers to Professors Marx, Wing, and Hoskins, of Leland Stanford, Junior, University.

EC refers to E. C. Clarke.

S refers to the writer, Fred. C. Scobey, irrigation engineer, in charge of experiments on the flow of water in channels and pipes.

Column 4 gives the observation number as carried by the experimenter.

Column 10 shows the value of n as computed from the observation.

Column 11 shows the value of n for a normal pipe of the same size at the observed velocity. This value is taken by inspection of the n curves in Plate VIII. The writer has termed this the normal value of n .

Columns 14 to 18, inclusive, show the velocities for the same size of pipe with the given loss of head (column 9) when computed by the various formulas.

Columns 19 to 23, inclusive, show the percentage comparison of observed velocities (column 8) to computed velocities (columns 14 to 18). This comparison is explained on page 55, in connection with the information in Plate VII. The grand algebraic means of all observations in the respective columns are given at the foot of the columns on page 37. These means are graphed in Plate VII and shown also on page 14. The other columns are self-explanatory.

EXPLANATORY NOTES ON TABLE 3.

Column 1 gives the same consecutive numbers of pipes as column 1, Table 2. See discussion after "Column 1" on page 26.

Column 2 gives the inclusive reference numbers of observations on that particular pipe, which are the same as those in column 2, Table 2.

Columns 10 to 14, inclusive, give the weights assigned to the determination of the general value of the exponent of V in formula 12, page 7. The method of finding these weights is explained on page 52.

Column 15 gives the weights assigned the various series in determining the general equation for the intercept curve shown in figure 4.

Column 16 gives the revised values of the intercepts for individual pipes as explained on page 53. Note that these may be quite different from the value representing the intercept in the equations shown in column 17.

Column 17 gives the formulas of flow, as shown by the observations, for the individual pipes. Their derivation is explained on page 53.

Columns 18 to 22, inclusive, have the same general significance as columns 19 to 23, Table 2, respectively. For the series the figures given are the algebraic means of the percentages for the observations. The grand algebraic means for all pipes are shown at the foot of the columns on page 39. These means are graphed in Plate VII, and are also given on page 14.

The other columns are considered self-explanatory.

TABLE 2.—Elements of experiments for the determination of friction losses in wood-stave pipes, with percentage comparison of observed velocities to formula velocities.

1	2	3	4	5	6	7	8	9	Coefficients of retardation.					Comparison, by various formulas, of observed to calculated velocities.									
														Velocities, by formulas, for given H , per second.									
														14	15	16	17	18	19	20	21	22	23
Pipe No.	Reference No.	Experimenter and year.	Observation.	P Diameter.	Name and description of pipe.	Discharge, per second.	Mean velocity, per second.	Loss of head, per 1,000 feet.	u observation, by	u Kutter, mal.	u Chezy.	u Williams-Hazen.	u Scobey.	Williams-Hazen ($C_w=120$).	Moritz.	Tutton.	Weisbach.	Scobey.	Williams-Hazen ($C_w=120$).	Moritz.	Tutton.	Weisbach.	P. cl.
1a	1	HS-X, 1877	339	1.26	New Almaden, Cal. 8 joints of heart redwood, bored with a pipe auger. New and straight.	Cu. ft. 0.014	Feet. 1.653	24.19	u observation, by	u Kutter, mal.	u Chezy.	u Williams-Hazen.	u Scobey.	Williams-Hazen ($C_w=120$).	Moritz.	Tutton.	Weisbach.	Scobey.	Williams-Hazen ($C_w=120$).	Moritz.	Tutton.	Weisbach.	P. cl.
2	2		338			0.021	2.469	50.94	65.5		67.5												
3	3		337			0.026	3.008	76.10	67.2		67.6												
4	4		336			0.031	3.519	103.06	67.9		67.9												
5	5		335			0.035	3.986	131.15															
6	6	EM, 1910	5	4.00	Sunnyside project, Washington. Jointed straight pipe on continuous down slope. Growth at inlet. Condition unknown.	0.37	425		0.018	0.0107	68.6	96.8	0.519	0.527	0.520	0.502	0.520	18.1	19.4	18.4	18.4	15.4	18.3
7	7		71			0.037	770	1.259	0.013	0.0101	75.2	102.2	0.902	0.904	0.906	0.856	0.901	14.6	14.8	15.0	15.0	8.1	14.6
8	8		6			0.091	1.046	2.209	0.012	0.0099	77.3	107.5	1.23	1.22	1.24	1.11	1.24	14.9	14.6	15.4	15.4	6.0	15.9
9	9		4			0.123	1.448	3.688	0.007	0.0097	82.8	102.6	1.64	1.62	1.64	1.45	1.64	11.6	10.4	11.8	11.8	0.1	11.4
10	10		3			0.146	1.678	4.905	0.006	0.0096	83.2	107.0	1.92	1.88	1.93	1.67	1.90	12.5	10.8	12.9	12.9	0.2	11.7
3a	11	EM, 1910	2	4.00	Another reach of pipe No. 2.	0.312	3.586	17.476	0.0098	0.0093	93.9	115.0	3.88	3.74	3.90	3.20	3.80	7.6	4.2	8.1	12.1	5.6	4.2
12	12		1			0.388	4.460	25.369	0.0096	0.0096	97.2	116.9	4.77	4.57	4.80	3.87	4.65	6.5	2.6	7.0	15.3	4.2	
4a	13	EM, 1909	5	5.00	Sunnyside project, Washington. Jointed inverted siphon. Straight in horizontal alignment.	0.057	419	243	0.004	0.010	83.8	118.3	419	425	425	416	420	0.0	1.4	1.1	1.1	0.7	0.2
14	14		6			0.089	654		0.007	0.0107	85.7	117.1	669	670	679	639	689	2.2	2.4	3.6	3.6	2.2	5.2
15	15		7			0.111	816	837	0.006	0.0104	87.8	118.1	830	812	844	781	848	1.7	1.5	2.4	2.4	4.4	3.8
16	16		1			0.136	1.000	1.312	0.008	0.0103	85.8	113.6	1.07	1.06	1.08	0.92	1.09	6.6	5.4	7.6	7.6	1.8	8.0
17	17		2			0.179	1.316	2.165	0.007	0.0100	87.2	114.0	1.41	1.38	1.43	1.27	1.46	6.6	5.0	8.1	8.1	3.8	9.9
18	18		8			0.199	1.463	2.481	0.004	0.0097	91.5	117.9	1.52	1.49	1.54	1.36	1.53	3.9	1.8	5.2	5.2	7.6	7.4
19	19		4			0.311	2.287	6.099	0.005	0.0097	91.2	113.3	2.50	2.42	2.54	2.15	2.47	8.5	5.6	10.0	10.0	6.3	4.5
20	20		3			0.313	2.301	6.292	0.006	0.0097	90.4	112.3	2.56	2.46	2.58	2.18	2.51	10.1	6.5	10.8	10.8	5.3	8.3

5a	21	EM, 1909	1	6.00	Sunnyside project, Washington. Jointed straight pipe on continuous down slope. Total length 1,000 feet.	.098 .162 .213 .234 .374	.499 .827 .1085 .1378 .1704	.250 .0104 .0103 .0102 .0102	.0104 .0107 .0105 .0103 .0101	.0112 .0107 .0105 .0103 .0101	.89.3 .94.7 .97.5 .98.3 .98.8	123.7 126.6 127.6 126.5 128.2	.480 .785 .783 1.31 1.63	.434 .784 1.02 1.33 1.67	.490 .805 1.06 1.33 1.67	.476 .750 .962 1.22 1.64	.504 .815 1.06 1.34 1.64	+3.9 +5.3 +5.3 +5.4 +4.5	+3.0 +5.5 +2.8 +1.3 +6.8	+1.7 +2.9 +2.9 +1.3 +2.1	+4.8 +10.2 +12.6 +13.4 +16.2	-0.9 -1.4 +2.8 +2.4 +3.8
6a	26	EM, 1910	5	6.00	Sunnyside project, Washington. Jointed inverted siphon. Curvature and profile similar to those discussed under pipe No. 11.	.079 .121 .159 .200 .294	.403 .490 .617 .811 1.090	.160 .0100 .0103 .0104 .0106	.0100 .0112 .0112 .0110 .0106	.0113 .0112 .0112 .0110 .0106	.90.2 .89.1 .90.7 .93.3 .91.9	127.1 124.1 123.7 124.6 120.7	.374 .408 .595 .783 .990	.380 .474 .610 .781 .986	.383 .479 .610 .802 1.02	.397 .495 .617 .806 1.07	.397 .495 .617 .806 1.07	+7.8 +3.6 +3.6 +3.6 +0.0	+5.9 +2.2 +3.2 +1.2 +0.6	+5.1 +2.2 +3.2 +1.2 +2.8	+6.4 +5.1 +6.2 +8.6 +6.2	+1.5 -1.0 +0.1 +0.6 +2.6
7a	32	EM, 1910	7	6.00	Sunnyside project, Washington. Same pipe as Nos. 6, 8.	.299 .456	1.526 2.327	.1973 .4295	.0103 .0101	.0103 .0100	.98.4 100.5	123.9 121.4	1.50 2.32	1.48 2.25	1.54 2.38	1.37 2.03	1.52 2.31	+1.7 +0.3	+3.2 +1.2	-1.0 -2.1	+11.6 +14.6	+0.5 +0.9
8a	34	EM, 1910	8	6.00	Sunnyside project, Washington.	.588	3.000	6.889	.0100	.0098	102.2	124.0	3.01	2.90	3.09	2.58	2.97	-0.3	+3.3	-2.8	+16.1	+1.1
9a	35	EM, 1909	2	8.00	Sunnyside project, Washington. Jointed inverted siphon. One bend in horizontal alignment. Same pipe covered by Nos. 10, 11, and 12.	.366 .469 .573 .745 .904	1.049 1.344 1.642 2.135 2.590	.847 1.304 1.853 2.988 4.498	.0116 .0114 .0112 .0111 .0111	.0110 .0108 .0107 .0103 .0103	.81.2 .91.1 .93.3 .95.6 .96.2	112.1 113.9 115.0 115.5 113.3	1.14 1.44 1.75 2.28 2.84	1.12 1.42 1.71 2.22 2.74	1.18 1.50 1.82 2.38 2.96	1.07 1.34 1.44 1.60 2.26	1.15 1.44 1.74 2.26 2.92	+7.8 +6.7 +6.1 +6.4 +8.7	-6.6 -5.1 -4.2 -3.7 -5.6	-11.1 -10.5 -9.9 -10.3 -12.5	-2.1 +0.6 +2.7 +3.2 +4.1	-8.8 -7.0 -5.9 -5.6 -6.7
10a	44	EM, 1909	10	8.00	Sunnyside project, Washington. See Nos. 9, 11, and 12.	.433 .782	1.241 2.241	1.114 3.270	.0114 .0110	.0108 .0103	.90.8 95.6	114.5 115.5	1.32 2.40	1.30 2.33	1.38 2.50	1.23 2.14	1.33 2.36	+6.0 -6.6	-4.6 -4.8	-9.7 -10.4	+0.6 +5.0	-6.8 -5.2
11a	46	EM, 1910	8	8.00	Sunnyside project, Washington. See Nos. 9, 10, and 12. Note great divergence in results on same pipe in years 1909 and 1910. Moritz suggests this is due to air conditions, which varied.	.575 .748 .905 1.169 1.315 1.484 1.656 2.050	1.648 2.143 2.593 3.350 3.708 4.252 5.106 5.874	1.257 .993 2.813 4.305 6.357 8.357 9.200 11.494	.0096 .0094 .0093 .0090 .0090 .0088 .0087 .0086	.0106 .0104 .0103 .0101 .0101 .0100 .0099 .0099	.113.4 117.1 119.3 124.5 126.0 130.0 131.4 133.9	142.4 145.0 145.0 148.9 149.5 153.1 152.4 153.7	1.41 1.82 2.21 2.80 3.45 3.48 4.26 4.84	1.39 1.78 2.15 2.70 3.02 3.33 4.06 4.59	1.47 1.90 2.30 2.91 3.27 3.62 4.44 5.02	1.31 1.65 1.85 2.22 2.78 3.11 3.62 4.17	1.44 1.85 2.22 2.78 3.11 3.43 4.17 4.65	+16.9 +17.7 +17.3 +20.7 +19.6 +24.5 +27.5 +21.3	+18.7 +20.2 +20.1 +24.1 +19.6 +24.5 +27.5 +28.1	+12.1 +12.7 +12.7 +15.0 +13.0 +17.8 +16.4 +16.9	+25.7 +29.2 +31.0 +36.4 +37.7 +41.8 +42.7 +44.9	+14.4 +16.1 +17.0 +20.4 +20.9 +24.0 +23.6 +25.2
12a	54	EM, 1910	12	8.00	Sunnyside project, Washington. See Nos. 9, 10, and 11.	.158 .182 .332 .423	.453 .521 .951 1.212	.161 .206 .527 .782	.0109 .0109 .0103 .0101	.0117 .0116 .0111 .0109	.87.1 88.8 101.0 105.8	118.8 119.8 131.4 135.3	.451 .518 .873 1.09	.458 .523 .836 1.07	.470 .539 .908 1.13	.460 .521 .842 1.03	.47 .535 .849 1.11	+0.4 +0.6 +9.5 +11.1	-1.0 -0.0 +9.5 +12.7	-3.6 -2.4 +4.8 +7.2	-1.5 -0.2 +5.7 +17.7	-3.6 -2.4 +5.7 +9.0

TABLE 2.—*Elements of experiments for the determination of friction losses in wood-stave pipes, with percentage comparison of observed velocities to formula velocities*—Continued.

Pipe No.	Reference No.	Experiment and year.	Observation.	Diameter. Inches.	Name and description of pipe.	Discharge, per second. Cu. ft.	Mean velocity, per second. Feet.	Loss of head, per 1,000 feet. Feet.	Coefficients of retardation.					Comparison, by various formulas, of observed to calculated velocities.									
									Kutter, by observation, by n	Kutter, normal, n	Chezy, C	Williams-Hazen, C _w	Scobey, Feet.	Velocities, by formulas, for given H, per second.					Column 8 compared to columns 14-18, inclusive.				
														14	15	16	17	18	19	20	21	22	23
13	58 59 60 61 62 63 64 65	S-12, 1914	2 3 3 4 5 6 7 7	8.00	French Bros. Jointed delivery pipe, laid on gentle grade upward. One bend in horizontal alignment. Interior condition unknown, but probably good as open canal clears water.	Cu. ft. 0.104 .327 .453 .608 .730 1.036 1.177 1.243	Feet. 0.316 .936 1.251 1.736 2.048 3.043 3.294 3.558	Feet. 0.116 .840 1.035 1.827 2.393 5.979 6.850 8.019	0.0123 0.0111 0.0109 0.0107 0.0105 0.0110 0.0109 0.0108	0.0121 0.0111 0.0109 0.0106 0.0104 0.0102 0.0102 0.0101	71.7 100.6 120.0 122.6 125.0 113.2 114.0 113.3	98.7 100.6 120.0 122.6 125.0 113.2 114.0 113.3	Feet. 0.378 1.13 1.12 1.25 1.70 3.22 3.47 3.77	Williams-Hazen (C _w =120).					Scobey.				
														14	15	16	17	18	19	20	21	22	23
														Feet.	Feet.	Feet.	Feet.	Feet.	P. ct.	P. ct.	P. ct.	P. ct.	P. ct.
														0.384	1.12	1.18	1.07	1.15	16.4	17.7	19.3	18.8	24.5
														1.13	1.25	1.32	1.19	1.30	17.2	16.2	20.4	18.4	24.6
														1.27	1.70	1.80	1.59	1.75	0.7	0.0	5.2	5.1	3.2
														1.75	1.80	2.10	1.82	2.03	1.5	2.1	3.6	9.2	0.6
14	66 67 68 69 70	S-11, 1914	5 1 1 4 2	10.00	Congdon Orchards, Washington. Jointed straight pipe with slight dip between gauges.	Cu. ft. 1.978 2.499 2.540 2.572 2.769	Feet. 3.633 4.585 4.66 4.72 5.08	Feet. 6.160 10.724 9.635 9.961 11.950	0.0111 0.0115 0.0109 0.0110 0.0112	0.0103 0.0102 0.0102 0.0102 0.0101	101.4 97.0 104.0 103.6 101.8	115.5 108.2 116.5 115.9 113.1	Feet. 3.95 5.07 5.04 5.14 5.68	Williams-Hazen (C _w =120).					Scobey.				
														3.77	4.15	4.32	3.81	3.81	8.0	3.6	12.6	6.2	4.6
														3.95	5.07	5.65	4.53	5.08	14.2	9.8	18.8	11.2	9.6
														5.25	5.04	5.33	4.29	4.82	7.5	2.9	12.7	7.5	3.4
														5.14	4.88	5.42	4.36	4.90	8.1	3.4	12.9	8.2	3.6
														5.68	5.39	6.00	4.79	5.44	10.5	5.8	15.2	6.1	6.6
														3.96	4.11	4.11	3.37	3.85	10.2	5.6	13.5	5.4	7.5
15a	71 72 73 74	C-1908 C-1908 C-1909 C-1911	2 1 3 4	10.12	Bonito pipe line, New Mexico. Not used by writer in deriving formula as maximum velocity is taken.	Cu. ft. 5.42 5.44 5.98 6.19	Feet. 9.705 9.74 10.71 11.07	Feet. 33.38 33.38 33.38 33.38	0.0087 0.0087 0.0087 0.0089	138 138 132 132	101.8 101.8 101.8 101.8	113.1 113.1 113.1 113.1	Feet. 5.68 5.68 5.68 5.68	Williams-Hazen (C _w =120).					Scobey.				
														3.77	4.15	4.32	3.81	3.81	8.0	3.6	12.6	6.2	4.6
														3.95	5.07	5.65	4.53	5.08	14.2	9.8	18.8	11.2	9.6
														5.25	5.04	5.33	4.29	4.82	7.5	2.9	12.7	7.5	3.4
														5.14	4.88	5.42	4.36	4.90	8.1	3.4	12.9	8.2	3.6
														5.68	5.39	6.00	4.79	5.44	10.5	5.8	15.2	6.1	6.6
														3.96	4.11	4.11	3.37	3.85	10.2	5.6	13.5	5.4	7.5
16a	75 76 77 78	EM, 1910	1 2 3 4	12.00	Sunnyside project, Washington. Jointed, machine banded pipe. Dip in profile. Probably silted as	Cu. ft. .360 .469 .581 .698	Feet. .459 .597 .740 .889	Feet. 1.139 2.22 .349 .459	0.0129 0.0130 0.0129 0.0130	0.0124 0.0122 0.0120 0.0118	78.0 80.2 78.2 82.9	100.9 102.0 99.0 102.6	Feet. 5.42 7.03 .897 1.04	Williams-Hazen (C _w =120).					Scobey.				
														5.42	5.68	5.68	4.79	5.44	15.4	15.8	20.6	17.6	19.8
														5.68	5.39	6.00	4.79	5.44	15.4	15.8	20.6	17.6	19.8
														3.77	4.15	4.32	3.81	3.81	8.0	3.6	12.6	6.2	4.6
														3.95	5.07	5.65	4.53	5.08	14.2	9.8	18.8	11.2	9.6
														5.25	5.04	5.33	4.29	4.82	7.5	2.9	12.7	7.5	3.4
														5.14	4.88	5.42	4.36	4.90	8.1	3.4	12.9	8.2	3.6

29	141	S-2 1914.	4	24.06	Butler Water Works, Pennsylvania. Jointed white-pine pipe on continuous down slope. Wire-wound.	2.690 2.824 2.886 3.570	.854 .897 .916 1.13	.128 .196 .202 .239	.0117 .0137 .0136 .0124	.0128 .0137 .0127 .0126	106.6 90.5 91.1 103.3	126.8 105.5 106.4 119.9	.815 1.03 1.04 1.15	.809 1.02 1.03 1.13	.894 1.13 1.15 1.26	.845 1.05 1.06 1.16	.911 1.13 1.16 1.26	+ 4.8 -12.8 -12.3 -1.7	+ 5.6 -12.1 -11.2 -0.1	- 4.4 -20.6 -20.2 -10.3	+ 1.0 -14.8 -39.9 -2.6	- 6.2 -20.5 -20.2 -10.3	
30	145	S-1 1914.	2	22.8	Norfolk County Water Co., Virginia. Jointed pipe.	2.608 2.615	.918 .926	.135 .156	.0110 .0116	.0127 .0147	114.4 107.6	136.6 127.8	.81 .87	.807 .871	.887 .960	.840 .903	.905 .998	+ 4.0 + 10.8	+ 13.8 + 6.4	+ 3.5 + 2.1	+ 1.3 + 4.3	- 6.2 - 4.3	
31	147	S-15 1914	2	24.00	Ogden Water Works, Utah. Continuous stave.	9.872 9.907	3.142 3.153	1.429 1.375	.0115 .0113	.0116 .0116	117.5 120.2	126.8 130.1	3.10 3.02	2.98 2.91	3.41 3.33	2.89 2.83	3.40 3.34	+ 1.3 + 4.3	+ 5.6 + 8.4	+ 7.8 + 5.2	+ 8.7 + 11.3	- 7.6 - 5.7	
32a	149	H-1892..	1	24.00	Butte Water Works, Montana.	3.6	1.147	.....	.0103	.0123	127.0	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....		
33a	150	DB-51	1	.....	Experimental pipe, closely jointed. Rectangular, 2.624 feet by 1.64 feet.	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....		
151	151	1887	2	.....	.....	1.666	.475	.0122	.0122	.0122	107.6	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....		
152	151	1887	3	.....	.....	2.519	1.076	.0123	.0123	.0117	108.1	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....		
153	152	.....	4	.....	.....	3.372	1.899	.0122	.0122	.0115	108.9	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....		
154	153	.....	5	.....	.....	4.225	2.911	.0122	.0122	.0112	110.2	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....		
155	154	.....	6	.....	.....	5.068	4.272	.0123	.0123	.0111	109.1	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....		
156	155	.....	7	.....	.....	5.527	5.063	.0123	.0123	.0110	109.3	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....		
157	156	.....	8	.....	.....	5.914	5.760	.0123	.0123	.0110	109.7	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....		
34a	158	JDS-1891	1	30.00	Denver Water Works, Colorado.	.....	.....	.0096	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....		
35a	159	JM-1911.	14	31.00	Sunnyside project, Washington. Continuous stave for siphon pipe. See also pipe No. 36. Intake from open feed canal, with high velocity in earth section.	3.05 3.85 4.94 5.90 6.87 8.90 21.32	.582 .735 .943 1.126 1.311 1.698 4.068	.063 .094 .142 .197 .267 .398 1.621	.0129 .0134 .0138 .0133 .0135 .0129 .0114	.0133 .0133 .0131 .0130 .0128 .0115 .0115	91.4 93.5 98.4 99.9 112.7 116.3 125.7	107.8 109.7 112.7 114.1 122.1 130.3 136.3	.645 .805 1.001 1.221 1.441 1.752 3.791	.647 .803 1.000 1.220 1.441 1.752 3.747	.720 .900 1.131 1.361 1.611 1.781 4.37	.695 .854 1.051 1.251 1.561 1.921 3.65	.744 .914 1.131 1.341 1.561 1.921 3.65	- 9.7 - 8.7 - 6.6 - 7.7 - 9.0 - 5.2 + 3.9	- 10.2 - 8.7 - 6.0 - 16.7 - 7.2 - 15.3 + 8.6	- 19.2 - 18.3 - 14.0 - 10.6 - 9.6 - 9.9 - 4.8 + 11.4	- 16.4 - 19.6 - 16.5 - 15.9 - 15.2 - 11.7 + 2.3	- 21.8 - 19.6 - 16.5 - 12.9 - 13.6 - 11.7 + 2.3	
36a	166	JM-1911.	8	31.00	Sunnyside project, Washington. This reach included in that covered by No. 35. Practically straight continuous down grade.	11.59 13.56 16.38 16.51 20.34 21.11 24.05	2.211 2.587 3.125 3.150 3.881 4.028 4.589	.757 .962 1.347 1.390 1.959 1.648 2.661	.0137 .0133 .0131 .0128 .0128 .0115 .0127	.0129 .0121 .0119 .0118 .0115 .0112 .0110	100.0 103.8 106.0 105.1 109.4 123.5 110.7	107.0 110.9 112.7 112.8 128.1 128.1 112.7	2.57 2.93 3.53 3.60 4.35 3.96 5.16	2.48 2.82 3.38 3.44 4.14 3.77 4.89	2.48 3.27 3.94 4.01 4.85 4.41 5.75	2.48 3.27 3.94 4.01 4.85 4.41 5.75	2.48 3.27 3.94 4.01 4.85 4.41 5.75	- 14.0 - 11.7 - 11.4 - 10.7 - 10.7 - 1.7 - 11.0	- 10.8 - 8.3 - 7.6 - 8.6 - 8.6 + 6.6 - 6.0	- 22.8 - 20.9 - 20.6 - 21.4 - 20.0 - 8.6 - 20.2	- 17.4 - 14.4 - 12.9 - 13.6 - 11.1 - 9.9 + 9.4	- 17.4 - 14.4 - 12.9 - 13.6 - 11.1 - 9.9 + 9.4	- 17.4 - 14.4 - 12.9 - 13.6 - 11.1 - 9.9 + 9.4
37	173	S-4 1914.	2	36.00	Pasco Reclamation Co., Washington. Continuous stave.	11.69 13.84	1.653 1.957	.360 .570	.0133 .0147	.0127 .0126	100.7 94.8	109.0 100.7	1.87 2.42	1.82 2.33	2.11 2.62	1.87 2.36	1.98 2.48	- 11.5 - 19.1	- 9.2 - 16.0	- 21.4 - 27.9	- 16.3 - 21.1	- 16.3 - 21.1	
38	175	S-5 1914.	1	36.00	Pasco Reclamation Co., Washington. Continuous stave.	15.30 16.01	2.164 2.265	.628 .636	.0141 .0136	.0124 .0123	99.8 103.9	106.5 110.8	2.55 2.57	2.44 2.45	2.87 2.89	2.48 2.50	2.62 2.65	- 15.1 - 11.8	- 11.3 - 7.7	- 24.5 - 21.5	- 17.3 - 14.4	- 17.3 - 14.4	
39	177	S-8 1914.	1	38.13	Burbank Co., Washington..	10.07	1.271	.142	.0117	.0131	119.6	133.4	1.16	1.14	1.31	1.21	1.26	+ 9.7 + 11.2	+ 2.7 + 5.3	+ 5.3 + 1.2	+ 1.2 + 1.2		

TABLE 2.—Elements of experiments for the determination of friction losses in wood-stave pipes, with percentage comparison of observed velocities to formula velocities—Continued.

Comparison, by various formulas, of observed to calculated velocities.																										
Coefficients of retardation.										Velocities, by formulas, for given H, per second.								Column 8 compared to columns 14-18, inclusive.								
Pipe No.	Reference No.	3	4	5	6	7	8	9	u				C ^a	Scobey.	Williams-Hazen (C ^w =120).	Mortiz.	Tutton.	Weissbach.	Scobey.	Williams-Hazen (C ^w =120).	Mortiz.	Tutton.	Weissbach.			
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23				
		Experiment and year.	Observation.	D Diameter.	Name and description of pipe.	Q Discharge, per second.	Δ Mean velocity, per second.	H Loss of head, per 1,000 feet.	u Kutter, by observation.	u Kutter, normal.	C Chezy.	C ^a Williams-Hazen.	Feet.	Feet.	Feet.	Feet.	Feet.	P. ct.	P. ct.	P. ct.	P. ct.	P. ct.				
40	179 180	S-6 1914.	2 3	Inches. 40.00	Burbank Co., Washington. Continuous stave fir.	Cu. ft. 18.03 18.56	Feet. 2.066 2.126	Feet. 0.401 .339	0.0118 .0116	0.0126 0.0125	113.0 126.6	120.1 135.4	2.14 1.94	2.07 1.88	2.41 2.19	2.12 1.94	2.26 2.06	-3.4 +9.5	+0.1 +12.8	-14.1 -3.0	-2.4 +9.5	-8.5 +3.1				
41a	181 182 183 184 185 186 187 188 189 190 191	N 1901..	1 2 3 4 5 6 7 11 10 9 8	Inches. 44.50	Seattle Water Works, Wash- ington. Continuous stave fir pipe. Practically straight. No interior growth. This reach down- stream from No. 44.	37.44 38.06 39.52 41.44 42.84 42.54 44.04 47.71 49.66 50.09 52.21	Feet. 3.464 3.522 3.685 3.853 3.964 3.972 4.075 4.415 4.595 4.635 4.831	Feet. 1.067 1.134 1.191 1.262 1.330 1.331 1.404 1.613 1.757 1.757 1.888	0.0134 0.0136 0.0133 0.0132 0.0131 0.0131 0.0131 0.0138 0.0130 0.0129 0.0129	0.0122 0.0121 0.0121 0.0121 0.0121 0.0121 0.0120 0.0119 0.0119 0.0119 0.0118	110.1 108.6 109.1 112.7 112.9 112.9 112.9 113.7 113.8 114.8 115.4	110.9 109.1 111.2 112.7 112.9 112.9 113.9 114.8 115.4 116.4 117.5	3.93 4.07 4.18 4.32 4.45 4.45 4.58 5.17 5.17 5.17 5.40	3.75 3.87 3.98 4.10 4.22 4.22 4.35 4.91 4.91 4.91 5.10	4.46 4.62 4.74 4.90 5.04 5.04 5.20 5.61 5.89 5.89 6.13	3.74 4.31 4.35 4.50 4.62 4.62 4.74 5.01 5.31 5.48 5.51	-11.8 -13.4 -11.8 -10.8 -10.9 -10.6 -11.1 -10.9 -11.1 -10.3 -10.5	-7.6 -9.0 -7.4 -6.3 -5.9 -6.0 -5.0 -6.3 -5.5 -5.1	-14.8 -23.7 -22.2 -21.3 -21.4 -21.2 -21.6 -21.4 -21.9 -21.2 -21.1	-7.5 -8.8 -6.9 -5.3 -5.3 -5.2 -5.4 -4.5 -3.9 -3.4 -3.4	-16.0 -18.2 -15.3 -14.2 -14.1 -13.6 -14.0 -13.4 -12.5 -11.8					
42	192 193 194 195 196	S-9 1914.	2 5 3 3 1	48.00	Cowiche siphon, Washing- ton. New inverted siphon. Steep legs joined by verti- cal curve. High velocity prevents silt.	38.32 46.62 57.83 59.43 59.09	3.14 3.75 4.61 4.75 4.84	.452 .649 1.095 1.143 1.174	.0105 .0104 .0110 .0110 .0112	.0123 .0122 .0120 .0119 .0118	147.7 147.2 139.3 140.5 137.2	152.4 149.7 138.8 139.7 140.2	2.56 3.13 4.18 4.30 4.36	2.47 3.01 3.98 4.08 4.14	2.92 3.57 4.77 4.89 4.90	2.54 3.05 3.99 4.08 4.13	2.81 3.52 4.79 4.87 4.94	+22.6 +19.8 +10.2 +10.5 +10.8	+27.3 +24.4 +15.6 +16.5 +16.9	+7.5 +5.0 -3.4 -2.8 -1.3	+23.6 +22.7 +15.6 +16.2 +17.0	+11.5 +6.6 -3.7 -2.5 -2.1				
43a	197 198 199	JM 1911.	1 2 3	48.75	Mabton pressure pipe. Sun- ny-side project, Washing- ton. Continuous stave.	30.0 36.4 46.2	2.315 2.809 3.565	.283 .335 .608	.0111 .0101 .0108	.0127 .0124 .0122	136.6 152.3 143.4	143.3 158.8 146.1	2.00 2.18 2.88	1.94 2.12 2.93	2.28 2.50 3.48	2.02 2.20 2.98	2.25 2.46 3.32	+15.6 +28.9 +14.3	+19.3 +32.3 +21.8	+1.7 +12.3 +2.4	+14.5 +27.5 +19.6	+2.8 +14.2 +7.4				

44a	2001	N 1901..	54. 19	Seattle Water Works, Wash- ington. Continuous stave fir pipe. Gentle curves. Some growths, Spongilla. On even gradient except one depression. Intake in low diversion dam from river. See No. 41.	2. 276/	. 342/	. 0131/	. 0128/115.8/	119. 1/	2. 23/	2. 29/	2. 72/	2. 38/	2. 66/	4. 6/	0. 7/	- 16. 4/	- 4. 8/	- 14. 5/
201	1	1	2. 282/	36. 53/	2. 282/	. 342/	. 0131/	. 0128/115.8/	119. 1/	2. 23/	2. 29/	2. 72/	2. 38/	2. 66/	4. 6/	0. 7/	- 16. 4/	- 4. 8/	- 14. 5/
202	2	2	2. 282/	36. 53/	2. 282/	. 342/	. 0131/	. 0128/115.8/	119. 1/	2. 23/	2. 29/	2. 72/	2. 38/	2. 66/	4. 6/	0. 7/	- 16. 4/	- 4. 8/	- 14. 5/
203	3	3	2. 282/	36. 53/	2. 282/	. 342/	. 0131/	. 0128/115.8/	119. 1/	2. 23/	2. 29/	2. 72/	2. 38/	2. 66/	4. 6/	0. 7/	- 16. 4/	- 4. 8/	- 14. 5/
204	4	4	2. 282/	36. 53/	2. 282/	. 342/	. 0131/	. 0128/115.8/	119. 1/	2. 23/	2. 29/	2. 72/	2. 38/	2. 66/	4. 6/	0. 7/	- 16. 4/	- 4. 8/	- 14. 5/
205	5	5	2. 282/	36. 53/	2. 282/	. 342/	. 0131/	. 0128/115.8/	119. 1/	2. 23/	2. 29/	2. 72/	2. 38/	2. 66/	4. 6/	0. 7/	- 16. 4/	- 4. 8/	- 14. 5/
206	6	6	2. 282/	36. 53/	2. 282/	. 342/	. 0131/	. 0128/115.8/	119. 1/	2. 23/	2. 29/	2. 72/	2. 38/	2. 66/	4. 6/	0. 7/	- 16. 4/	- 4. 8/	- 14. 5/
207	7	7	2. 282/	36. 53/	2. 282/	. 342/	. 0131/	. 0128/115.8/	119. 1/	2. 23/	2. 29/	2. 72/	2. 38/	2. 66/	4. 6/	0. 7/	- 16. 4/	- 4. 8/	- 14. 5/
208	8	8	2. 282/	36. 53/	2. 282/	. 342/	. 0131/	. 0128/115.8/	119. 1/	2. 23/	2. 29/	2. 72/	2. 38/	2. 66/	4. 6/	0. 7/	- 16. 4/	- 4. 8/	- 14. 5/
209	9	9	2. 282/	36. 53/	2. 282/	. 342/	. 0131/	. 0128/115.8/	119. 1/	2. 23/	2. 29/	2. 72/	2. 38/	2. 66/	4. 6/	0. 7/	- 16. 4/	- 4. 8/	- 14. 5/
210	10	10	2. 282/	36. 53/	2. 282/	. 342/	. 0131/	. 0128/115.8/	119. 1/	2. 23/	2. 29/	2. 72/	2. 38/	2. 66/	4. 6/	0. 7/	- 16. 4/	- 4. 8/	- 14. 5/
211	11	11	2. 282/	36. 53/	2. 282/	. 342/	. 0131/	. 0128/115.8/	119. 1/	2. 23/	2. 29/	2. 72/	2. 38/	2. 66/	4. 6/	0. 7/	- 16. 4/	- 4. 8/	- 14. 5/
45a	212	EM 1909.	55. 75	Mabton pressure pipe. Con- tinuous stave fir siphon pipe. This reach on con- tinuous down slope. In- take from open canal.	1. 814/	. 149/	. 0111/	. 0129/139.8/	139. 6/	1. 53/	1. 56/	1. 75/	1. 97/	1. 82/	1. 22/	1. 16/	1. 22/	1. 82/	1. 82/
213	213	213	2. 610/	44. 32/	2. 610/	. 066/	. 0108/	. 0129/143.1/	143. 1/	1. 81/	1. 86/	2. 10/	1. 97/	1. 82/	1. 22/	1. 16/	1. 22/	1. 82/	1. 82/
214	214	214	2. 610/	44. 32/	2. 610/	. 066/	. 0108/	. 0129/143.1/	143. 1/	1. 81/	1. 86/	2. 10/	1. 97/	1. 82/	1. 22/	1. 16/	1. 22/	1. 82/	1. 82/
215	215	215	2. 610/	44. 32/	2. 610/	. 066/	. 0108/	. 0129/143.1/	143. 1/	1. 81/	1. 86/	2. 10/	1. 97/	1. 82/	1. 22/	1. 16/	1. 22/	1. 82/	1. 82/
46a	216	EM 1910.	55. 75	Mabton pressure pipe. Same reach as No. 45, one year later. This pipe rebuilt in 1915. Tests show this pipe far smoother than normal. Probably no sediment in this reach. See Nos. 43 and 45.	1. 246/	. 086/	. 0117/	. 0135/124.6/	124. 6/	1. 12/	1. 16/	1. 29/	1. 26/	1. 34/	1. 22/	1. 16/	1. 22/	1. 82/	1. 82/
217	217	217	1. 513/	25. 70/	1. 513/	. 114/	. 0115/	. 0133/131.4/	131. 4/	1. 30/	1. 35/	1. 51/	1. 45/	1. 57/	1. 46/	1. 40/	1. 46/	1. 46/	1. 46/
218	218	218	1. 862/	31. 44/	1. 862/	. 163/	. 0114/	. 0131/134.6/	134. 6/	1. 80/	1. 64/	1. 84/	1. 74/	1. 88/	1. 57/	1. 43/	1. 57/	1. 57/	1. 57/
219	219	219	2. 409/	40. 80/	2. 409/	. 259/	. 0112/	. 0127/138.6/	138. 6/	2. 07/	2. 10/	2. 38/	2. 28/	2. 38/	1. 46/	1. 46/	1. 46/	1. 46/	1. 46/
220	220	220	2. 875/	48. 82/	2. 875/	. 350/	. 0110/	. 0126/142.5/	142. 5/	2. 45/	2. 47/	2. 82/	2. 58/	2. 77/	1. 46/	1. 46/	1. 46/	1. 46/	1. 46/
221	221	221	3. 068/	52. 10/	3. 068/	. 397/	. 0110/	. 0125/144.1/	144. 1/	2. 63/	2. 63/	3. 02/	2. 75/	2. 96/	1. 46/	1. 46/	1. 46/	1. 46/	1. 46/
222	222	222	3. 415/	57. 98/	3. 415/	. 483/	. 0109/	. 0123/144.1/	144. 1/	2. 93/	2. 94/	3. 36/	3. 04/	3. 26/	1. 46/	1. 46/	1. 46/	1. 46/	1. 46/
223	223	223	3. 788/	64. 32/	3. 788/	. 583/	. 0108/	. 0122/145.4/	145. 4/	3. 25/	3. 26/	3. 74/	3. 34/	3. 59/	1. 46/	1. 46/	1. 46/	1. 46/	1. 46/
224	224	224	3. 937/	66. 85/	3. 937/	. 602/	. 0106/	. 0122/148.7/	148. 7/	3. 31/	3. 31/	3. 80/	3. 40/	3. 65/	1. 46/	1. 46/	1. 46/	1. 46/	1. 46/
47a	225	MWH 1897	72. 5	Pioneer Electric Power Co., Ogden, Utah. Continu- ous stave fir pipe. New. Both vertical and horizon- tal curves, maximum of latter 10 degrees. (R. 573 ft.)	. 534/	. 040/	. 0204/	.....	69	. 872/	. 867/	1. 02/	. 969/	1. 11/	1. 11/	1. 11/	1. 11/	1. 11/	1. 11/
226	226	226	15. 6/	15. 6/	15. 6/	. 025/	. 0100/	.....	88	. 672/	. 672/	. 784/	. 703/	. 884/	1. 11/	1. 11/	1. 11/	1. 11/	1. 11/
227	227	227	19. 1/	19. 1/	19. 1/	. 066/	. 0109/	.....	73	1. 04/	1. 03/	1. 21/	1. 14/	1. 34/	1. 11/	1. 11/	1. 11/	1. 11/	1. 11/
228	228	228	23. 4/	23. 4/	23. 4/	. 020/	. 0100/	.....	148	1. 04/	1. 03/	1. 21/	1. 14/	1. 34/	1. 11/	1. 11/	1. 11/	1. 11/	1. 11/
229	229	229	34. 9/	34. 9/	34. 9/	. 095/	. 0153/	. 0137/101/	105. 6/	1. 41/	1. 38/	1. 64/	1. 51/	1. 73/	1. 11/	1. 11/	1. 11/	1. 11/	1. 11/
230	230	230	35. 2/	35. 2/	35. 2/	1. 228/	. 100/	. 0153/	. 0136/100/	103. 2/	1. 45/	1. 42/	1. 69/	1. 55/	1. 11/	1. 11/	1. 11/	1. 11/	1. 11/
231	231	231	33. 6/	33. 6/	33. 6/	1. 242/	. 095/	. 0148/	. 0136/104/	107. 9/	1. 41/	1. 38/	1. 64/	1. 51/	1. 73/	1. 11/	1. 11/	1. 11/	1. 11/
232	232	232	38. 2/	38. 2/	38. 2/	1. 332/	. 106/	. 0145/	. 0136/106/	108. 1/	1. 49/	1. 46/	1. 74/	1. 59/	1. 87/	1. 11/	1. 11/	1. 11/	1. 11/
233	233	233	42. 5/	42. 5/	42. 5/	1. 452/	. 111/	. 0135/	. 0136/115/	118. 3/	1. 53/	1. 50/	1. 79/	1. 63/	1. 87/	1. 11/	1. 11/	1. 11/	1. 11/
234	234	234	43. 8/	43. 8/	43. 8/	1. 876/	. 181/	. 0138/	. 0134/114/	115. 2/	2. 01/	1. 95/	2. 35/	2. 09/	2. 40/	1. 46/	1. 46/	1. 46/	1. 46/
235	235	235	56. 7/	56. 7/	56. 7/	1. 978/	. 211/	. 0141/	. 0133/111/	111. 8/	2. 19/	2. 12/	2. 55/	2. 26/	2. 59/	1. 46/	1. 46/	1. 46/	1. 46/
236	236	236	61. 3/	61. 3/	61. 3/	2. 138/	. 211/	. 0132/	. 0133/120/	122. 3/	2. 19/	2. 12/	2. 55/	2. 26/	2. 59/	1. 46/	1. 46/	1. 46/	1. 46/
237	237	237	63. 6/	63. 6/	63. 6/	2. 218/	. 235/	. 0135/	. 0132/117/	118. 2/	2. 32/	2. 25/	2. 71/	2. 39/	2. 73/	1. 46/	1. 46/	1. 46/	1. 46/
238	238	238	72. 7/	72. 7/	72. 7/	2. 536/	. 300/	. 0134/	. 0130/119/	118. 4/	2. 67/	2. 57/	3. 12/	3. 10/	3. 40/	1. 46/	1. 46/	1. 46/	1. 46/
239	239	239	77. 1/	77. 1/	77. 1/	2. 689/	. 331/	. 0133/	. 0130/120/	119. 2/	2. 82/	2. 70/	3. 29/	2. 85/	3. 26/	1. 46/	1. 46/	1. 46/	1. 46/
240	240	240	79. 8/	79. 8/	79. 8/	2. 783/	. 361/	. 0134/	. 0129/119/	117. 8/	2. 96/	2. 83/	3. 46/	2. 97/	3. 40/	1. 46/	1. 46/	1. 46/	1. 46/
241	241	241	90. 3/	90. 3/	90. 3/	3. 149/	. 452/	. 0132/	. 0128/121/	117. 9/	3. 36/	3. 20/	3. 91/	3. 33/	3. 81/	1. 46/	1. 46/	1. 46/	1. 46/
242	242	242	99. 0/	99. 0/	99. 0/	3. 453/	. 517/	. 0129/	. 0127/124/	120. 2/	3. 62/	3. 44/	4. 22/	3. 57/	4. 27/	1. 46/	1. 46/	1. 46/	1. 46/
243	243	243	102. 3/	102. 3/	102. 3/	3. 568/	. 566/	. 0132/	. 0126/122/	118. 8/	3. 80/	3. 60/	4. 44/	3. 74/	4. 27/	1. 46/	1. 46/	1. 46/	1. 46/
244	244	244	103. 7/	103. 7/	103. 7/	3. 637/	. 591/	. 0123/	. 0125/131/	127. 8/	3. 56/	3. 40/	4. 17/	3. 53/	4. 23/	1. 46/	1. 46/	1. 46/	1. 46/
245	245	245	104. 0/	104. 0/	104. 0/	3. 627/	. 591/	. 0123/	. 0125/126/	122. 8/	3. 72/	3. 55/	4. 35/	3. 68/	4. 23/	1. 46/	1. 46/	1. 46/	1. 46/
246	246	246	104. 5/	104. 5/	104. 5/	3. 645/	. 576/	. 0130/	. 0125/123/	120. 3/	3. 84/	3. 64/	4. 48/	3. 77/	4. 23/	1. 46/	1. 46/	1. 46/	1. 46/

TABLE 2.—Elements of experiments for the determination of friction losses in wood-stave pipes, with percentage comparison of observed velocities to formula velocities—Continued.

1	2	3	4	5	6	7	8	9	Coefficients of retardation.					Velocities, by formulas, for given H, per second.					Comparison, by various formulas, of observed to calculated velocities.				
Pipe No.	Reference No.	Experimenter and year.	Observation.	D. Diameter.	Name and description of pipe.	Q Discharge, per second.	Δ Mean velocity, per second.	H Loss of head, per 1,000 feet.	n Kutter, by observation.	n Kutter, mal.	C Chezy.	C ^a Williams-Hazen.	Scobey.	Williams-Hazen (C _w =120).	Mortz.	Tutton.	Welsbach.	Scobey.	Williams-Hazen (C _w =120).	Mortz.	Tutton.	Welsbach.	
48a	247 248 249 250 251 252 253 254 255 256 257 258 259 260 261	MWH 1899	J N L I Q 67 K M 63 P 39 R U T S	72.5	Pioneer Electric Power Co., Ogden, Utah. Longer reach of same pipe as No. 47. Two years interval between tests. Each lettered series the mean of several observations.	Cu. ft. 33.68 35.66 60.94 61.41 83.72 2.920 85.63 92.85 3.239 3.324 95.28 99.60 3.474 3.527 3.750 107.51 127.26 134.57 4.439 9.99 138.89 4.845 151.34	Feet. 1.175 1.244 2.126 2.144 2.920 3.78 2.987 3.239 3.324 3.474 3.527 3.750 107.51 127.26 134.57 4.439 9.99 138.89 4.845 151.34	Feet. 0.066 0.074 0.206 0.213 0.378 0.396 0.474 0.498 0.542 0.557 0.644 0.889 0.931 1.027 1.242 1.242	n Kutter, by observation.	n Kutter, mal.	C Chezy.	C ^a Williams-Hazen.	Scobey.	Williams-Hazen (C _w =120).	Mortz.	Tutton.	Welsbach.	Scobey.	Williams-Hazen (C _w =120).	Mortz.	Tutton.	Welsbach.	
49a	262	EC-1884	1	.....	Moon Island Conduit.	.....	4.8	.843	.0120	.0122	135	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	
50	265	S-16, 1915	1	78.00	Mohawk Hydro Electric Co., New York. Continuous stave fir pipe. Gentle curves, both horizontally and vertically. Water from reservoir. Pipe prob-	30.2 31.95 30.00 68.5 72.4 77.3	.911 .963 1.506 2.063 2.18 2.33	.053 .069 .115 .194 .215 .244	.0165 .0170 .0144 .0139 .0136	.0138 .0138 .0136 .0134 .0131 .0131	94.9 90.9 110.1 116.4 116.6 117.0	98.8 95.6 113.2 116.4 117.1 117.0	1.12 1.24 1.64 2.20 2.32 2.50	1.11 1.21 1.60 2.12 2.23 2.39	1.32 1.45 1.63 2.28 2.39 2.91	1.23 1.34 1.74 2.28 2.39 2.55	1.47 1.62 2.09 2.74 2.87 3.06	18.7 22.0 8.2 6.2 6.1 6.7	17.7 20.4 5.6 3.1 2.4 2.4	31.0 33.6 22.8 19.8 19.8 19.8	25.8 28.2 13.5 9.6 8.8 8.6	38.0 40.6 27.9 24.8 23.9 23.9	

[illegible]

TABLE 3.—Summary of pipes.—Also weights used in finding general exponent of V , in new formula; values of m' ; individual pipe formulas and comparison between observed and calculated velocities.

Pipe No.	1	2	3	4	5	6	7	8	9	Weights used in determining general exponent for V.						15	16	17	Means, by pipes, of percentages in columns 19 to 23, inclusive, Table 2.				
Reference No. for observations.			Experimenter.	Age of pipe, years.	Diameter of bore.	Diameter of bore.	Length of reach tested.	Area of bore.	Range of velocities, per second.	Number of observations.	Distribution of observations.	Range of observations.	Range of velocities.	Total weight for exponent, X.	Weight for intercept.	Revised intercept, m'.	Individual pipe formulas, before revising value of intercept, m to m'.	Scobey.	Williams-Hazen (C _w =120).	Moritz.	Tutton.	Weisbach.	
1a	1-5		Hamilton Smith...	0	Inches.	Feet.	Feet.	Sq. ft.	Feet.							0	2,006	H=1.99 V ^{1.723}	-12.3	-11.0	-12.7	-00.3	-11.7
2a	6-10		E. A. Moritz...	3	4.00	0.33	603.0	0.087	1,653-3,986	5	7.5	0	0	1,000	0	3	1,715	H=1.27 V ^{1.896}	-4.9	-3.7	-6.2	-4.0	-5.9
3a	11-12		do.	3	4.00	0.33	1,109.5	0.087	3,586-4,460	8	8.9	15.9	3.8	1,000	0	3	1,277	H=0.869 V ^{1.868}	+4.5	+5.4	+2.2	+1.4	+1.9
4a	13-20		do.	2	5.00	0.42	1,822.0	0.136	419-2,301	5	6.6	11.0	2.4	898	3	3	869	H=0.869 V ^{1.868}	+3.8	+3.6	+1.3	+7.5	0
5a	21-25		do.	3	6.00	0.50	500.4	0.196	499-1,704	6	6.6	10.6	1.8	755	3	3	882	H=0.908 V ^{1.877}	+1.0	+2.2	-1.5	+13.1	+0.7
6a	26-31		do.	3	6.00	0.50	1,801.0	0.196	403-1,281	2	0	0	0	0	1	1	929	H=0.908 V ^{1.877}	+0.3	+3.3	-2.8	+16.1	+1.1
7a	32-33		do.	3	6.00	0.50	1,892.0	0.196	1,523-2,327	2	0	0	0	0	0	0	794	H=0.745 V ^{1.867}	-7.5	-4.5	-11.1	+4.2	-6.1
8a	34		do.	3	6.00	0.50	2,021.0	0.196	3,000	1	0	0	0	0	0	0	759	H=0.745 V ^{1.867}	-6.3	-4.5	-11.1	+4.2	-6.1
9a	35-43		do.	5	8.00	0.67	3,394.5	0.349	1,049-4,407	9	7.1	12.8	6.8	1,000	2	2	488	H=0.528 V ^{1.724}	+19.5	+23.8	+14.8	+36.2	+20.2
10a	44-45		do.	5	8.00	0.67	2,002.0	0.349	1,241-2,241	2	0	0	0	0	0	0	614	H=0.576 V ^{1.690}	+5.2	+5.3	+1.3	+7.2	+2.2
11a	46-53		do.	1.5	8.00	0.67	3,515.2	0.349	1,648-5,874	2	8	11.1	8.4	1,000	2	2	782	H=0.576 V ^{1.690}	-7.8	-5.5	-11.2	+1.4	-8.1
12a	54-57		do.	1.5	8.00	0.67	4,054.9	0.349	453-1,212	2	8	10.4	19.2	6.6	1,000	3	612	H=0.800 V ^{1.766}	-9.7	-5.1	-14.4	+6.0	-5.6
13a	58-65		Fred. C. Scobey	7	10.00	0.83	1,503.0	0.545	3,163-5,558	8	10.5	3.6	3.0	30	30	0	560	H=0.555 V ^{1.728}	+5.6	+7.4	-1.3	+9.1	+2.3
14a	66-70		J. L. Campbell	0-3	10.12	0.84	12,700	0.554	970-11.7	4	0	0	0	0	0	0	334	H=0.341 V ^{1.790}	-3.8	+1.9	-10.4	+13.0	+1.6
15a	71-74		E. A. Moritz	3	12.00	1.00	2,022.0	0.785	459-1,803	7	7.3	12.0	2.8	1,000	3	3	305	H=0.296 V ^{1.890}	+8.7	+9.5	+1.9	+8.8	+3.6
16a	75-81		do.	4	14.00	1.17	3,637.0	1.069	495-3,267	8	9.9	16.1	5.4	1,000	3	3	377	H=0.296 V ^{1.890}	+17.3	+22.3	+8.5	+27.6	+15.2
17a	82-89		do.	4	14.00	1.17	3,637.0	1.069	572-2,64	7	8.0	14.0	4.4	1,000	3	3	300	H=0.296 V ^{1.890}	+17.3	+22.3	+8.5	+27.6	+15.2
18a	90-97		do.	5	14.00	1.17	2,517	1.069	622-6,24	2	0	0	0	0	0	0	194	H=0.296 V ^{1.890}	+10.8	+12.9	+2.4	+12.4	+5.4
19a	98-100		Fred. C. Scobey	5	14.00	1.17	2,517	1.069	622-6,24	2	0	0	0	0	0	0	290	H=0.296 V ^{1.890}	+18.0	+20.0	+9.0	+19.2	+12.2
20a	101-107		A. L. Adams	5	14.00	1.17	Various	1.08	691-1,531	7	0	0	0	0	0	0	290	H=0.296 V ^{1.890}	-6.0	-2.7	-12.9	+0.4	-6.6
21a	108-111		J. L. Campbell	0-3	16.12	1.34	47,500	1.396	3,791-4,37	8	0	0	0	0	0	0	197	H=0.161 V ^{2.776}	+3.0	+5.5	-5.6	+5.8	-0.7
22a	112-119		Darcy and Bazin	1	18.00	1.50	Text	1.54	1,230-5,307	8	0	0	0	0	0	0	194	H=0.161 V ^{2.776}	+17.3	+22.3	+8.5	+27.6	+15.2
23a	120-121		A. L. Adams	1	18.00	1.50	2,802.5	1.767	2,194-3,418	3	0	0	0	0	0	0	210	H=0.161 V ^{2.776}	+10.8	+12.9	+2.4	+12.4	+5.4
24a	122-124		E. A. Moritz	2	18.00	1.50	2,774.2	1.767	542-1,398	5	4.6	8.2	1.8	340	340	3	218	H=0.215 V ^{1.703}	+18.0	+20.0	+9.0	+19.2	+12.2
25a	125-129		do.	2	18.00	1.50	1,757.5	1.767	1,12-1,97	2	0	0	0	0	0	0	196	H=0.215 V ^{1.703}	+18.0	+20.0	+9.0	+19.2	+12.2
26a	130-131		Fred. C. Scobey	1	18.00	1.50	1,757.5	1.767	2,077-2,277	2	0	0	0	0	0	0	290	H=0.215 V ^{1.703}	-6.0	-2.7	-12.9	+0.4	-6.6
27a	132-133		do.	1	18.00	1.50	1,479.1	1.767	2,077-2,277	2	0	0	0	0	0	0	290	H=0.215 V ^{1.703}	+3.0	+5.5	-5.6	+5.8	-0.7
28a	134-140		E. A. Moritz	4	22.00	1.83	2,087.0	2.640	657-3,128	7	9.7	16.1	4.8	1,000	2	2	197	H=0.161 V ^{2.776}	+3.0	+5.5	-5.6	+5.8	-0.7

29	141-144	Fred. C. Scooby	7	24.00	2.01	1,957.71	3.15	884-1.13	21	0	0	0	0	0	0	207	-5.5	-4.4	-13.9	-7.6	-14.4																	
30	145-146	do.	2	22.8	1.90	1,077.5	2.831	918-.926	2	0	0	0	0	0	0	168	+7.4	+10.1	0.0	+5.8	-1.5																	
31	147-148	do.	24	24.00	2.00	2,240.7	3.142	3,142-3.153	2	0	0	0	0	0	0	177	+2.8	+7.0	-6.5	+10.0	-6.6																	
32a	149	D. C. Henry	0	24.00	2.00	18,389.0	3.142	1.147	1	0	0	0	0	0	0	0																						
33a	150-157	Darcy and Bazin				289.6	4.3	1,666-6.373	8	0	0	0	0	0	0	0																						
34a	158	J. D. Schuyler	0	30	2.5				1	0	0	0	0	0	0	0																						
35a	159-165	J. S. Moore	0	31	2.58	7,354.0	5.241	582-4.063	7	8.0	16.5	6.8	1,000	0	0	156	-6.1	-4.7	-16.0	-7.7	-14.2																	
36a	166-172	do.	0	31	2.58	4,513.5	5.241	2,211-4.589	7	3.3	6.3	4.8	700	0	0	167	-9.9	-5.9	-19.2	-3.9	-11.2																	
37	173-174	Fred. C. Scooby	0	36.00	3.00	516.0	7.069	1,653-1.957	2	0	0	0	0	0	0	158	-15.3	-12.6	-24.6	-14.2	-9.5																	
38	175-176	do.	0	36.00	3.00	538.1	7.069	2,164-2.265	2	0	0	0	0	0	0	151	-13.3	-9.5	-23.0	-10.9	-15.8																	
39	177	do.	1	38.13	3.18	5,965.9	7.922	1,271	2	0	0	0	0	0	0	169	+3.0	+6.4	-2.7	+5.3	+1.2																	
40	179-180	do.	1.5	40.00	3.33	927.4	8.727	2,006-2.126	2	0	0	0	0	0	0	162	+3.0	+6.4	-2.7	+5.3	+2.7																	
41a	181-191	T. A. Noble	1	44.5	3.71	4,041.0	10.81	3,404-4.831	8	1.6	2.8	3.0	125	0	0	112	-11.2	-11.2	-20.1	-1.0	-19.0																	
42	192-193	Fred. C. Scooby	1.5	48.00	4.00	887.4	12.57	3.14	4.2	4.1	4.6	3.4	150	0	0	105	+14.8	+20.2	+1.0	+19.0	+2.0																	
43a	197-199	J. S. Moore	2	48.75	4.06	1,341.0	12.96	2,315-3.565	3	0	0	0	0	0	0	058	-19.6	+21.5	+5.5	+20.5	+8.1																	
44a	200-210	T. A. Noble	1	54.19	4.52	2,446.7	16.05	2,276-4.688	11	3.8	6.2	5.0	1,000	0	0	074	-21	+2.5	-14.3	+0.6	+10.0																	
45a	211-215	E. A. Moritz	1.5	55.75	4.65	848.2	16.98	1,814-3.145	5	3.2	4.7	2.6	196	0	0	049	+18.3	+16.5	+2.8	+11.0	+3.2																	
46a	216-224	do.	1.5	55.75	4.65	848.2	16.98	1,246-3.937	9	6.0	9.8	5.2	1,000	0	0	053	-7.8	-5.1	-20.8	-11.2	-22.7																	
47a	225-240	Marx-Wing-Iloskins	1	72.5	6.04	2,710.0	28.6	534-3.645	17	8.9	16.2	6.2	1,000	0	0	030	-5.2	-0.7	-18.6	-5.0	-16.9																	
48a	247-261	do.	3	72.5	6.04	2,710.0	28.6	1,175-5.279	15	6.8	14.3	8.2	1,000	0	0	056	-9.6	-6.5	-22.9	-13.3	-27.8																	
49a	262	E. C. Clarke	4	78.00	6.5	2,486.5	36	4.8	1	0	0	0	0	0	0	0	-9.6	-6.5	-22.9	-13.3	-27.8																	
50a	263-271	Fred. C. Scooby	5	144.00	12.0	2,169.3	113.1	911-2.59	8	1.7	3.6	4.5	229	0	0	024	-2.4	+4.3	-18.9	-1.0																		
51	272-281	do.	1	144.00	12.0	2,169.3	113.1	5.94	8.22	3.4	5.5	5.1	477	0	0	016	+15.4	+21.5	-5.6	+11.5																		
52	282-286	do.	1	162.00	13.5	2,378.9	142.9	3.50	-6.10	5																												
Total plus																																						
Total minus																																						
Net difference, plus,																																						
Net difference, minus,																																						
Number of items																																						
Grand average, per cent.																																						

DESCRIPTION OF PIPES.

The descriptions in the following pages are to be taken as supplementing Tables 2 and 3. The methods of determining the hydraulic elements necessary for each observation are described. The descriptions of pipes upon which previous experimenters have made observations are given in the appendix.

No. 13, Expt. S-12, 8-inch Machine-Banded Douglas Fir Pipe, French Brothers' Orchard, North Yakima, Wash.—From the lower end of the 10-inch pipe discussed as No. 14 a reach 1,751.5 feet long of 8-inch machine-banded pipe affords exceptional opportunity for investigation. This pipe conveys water to a high point in the orchard, from which it is distributed in open ditches. There are two taps in the line within the reach between the gauges. First is a $1\frac{1}{4}$ -inch tap for lawn sprinkling; second, a 4-inch valve for irrigation purposes. These were closed tightly throughout the tests. Gauge No. 1, a mercury manometer, was placed 219 feet from the inlet valve. Gauge No. 2 was located 1,503 feet from gauge No. 1. For runs 1, 6, and 7 a water column was used. For runs 2, 3, 4, 5, and 8 a mercury manometer was used. An 8-inch control valve is located 17.5 feet downstream from gauge No. 2. A vertical iron pipe the same size as the wood pipe rises above the ground surface at this valve and discharges into a wooden division box. All but one ditch leading from this box were plugged with earth so that all the water was discharged at one end of the division box. This was equipped with a well-made Cipolletti weir 1.05 feet long. After run 3 this weir was removed and a rectangular weir, with end contractions suppressed, was built in its place. This weir was 2.84 feet long. Both weirs had clean-cut, sharp crests of galvanized iron. The change in weirs was necessary for the reason that it was desirable to run more water than could be accommodated through the Cipolletti weir and still maintain so-called standard conditions. The weirs were about 7 feet from the point where the water was turbulently discharged from the 8-inch pipe. From the place of impact to within about 2 feet of the weirs the box was filled with fresh-cut cottonwood branches and leaves. This mass formed an excellent screen from which the water emerged in good condition for weir measurement. A hook-gauge reading to thousandths of a foot was placed in the box above the weir. This permitted a direct comparison between the velocity in the pipe as determined with fluorescein and the velocity as determined by dividing the weir discharge by the nominal area of the pipe section. This comparison is shown in Table 1. The reach of pipe tested was without vertical curvature and had but one bend of about 20° about midway in its length. According to the best information available this pipe is about 7 years old and is used about 7 months of the year. It is buried about 3 feet below the surface and shows no signs of decay. The pipe capacity was approximately 8 per cent less than the discharge computed by the new formula.

No. 14, Expt. S-11, 10-inch Jointed Machine-Banded Douglas Fir Pipe, Congdon Orchards, North Yakima, Wash.—Irrigation water for the Congdon Orchards is conveyed from the main canal of the Yakima Valley Canal Co. in a 14-inch pipe (No. 19). From the lower end of this pipe a 10-inch pipe extends about one-half mile with a right angle bend about midway. A reach 1,297.4 feet long and without vertical or horizontal curvature was chosen at the lower end of the pipe, which was 7 years old at time of test and appeared to be free from leakage. The nominal size of the pipe was accepted as correct. Velocity was measured with fluorescein, the mean velocity shown by four batches of color for each run being accepted. The appearance of the color was awaited at a 6-inch hydrant 55 feet downstream from gauge No. 2. The color was injected at gauge No. 1. As the intake of this pipe line from the open canal is several miles from the river and the velocity in the pipe is rather high, it is improbable that there was any silt in the reach tested,

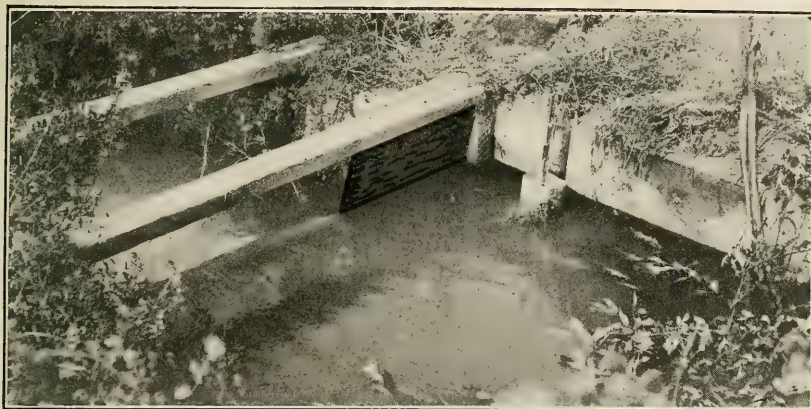


FIG. 1.—TYPICAL CIPOLLETTI WEIR, WITH HOOK GAUGE IN STILLING BOX.
Note brush screen in foreground to reduce velocity of approach.

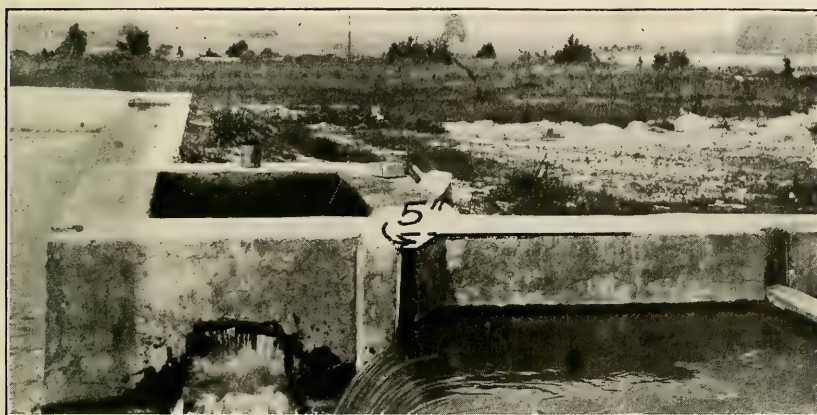


FIG. 2.—WEIR AT OUTLET OF PIPE NO. 30, NORFOLK COUNTY WATER CO., VIRGINIA.
The immediate bottom contraction similar to that shown at side, although water above weir wall is several feet deep.



FIG. 3.—TANK OF BUTLER (PA.) WATER CO. USED IN MEASURING DISCHARGE OF PIPE NO. 29.



FIG. 1.—THUMB POINTS TO TOP OF PIEZOMETER COLUMN (GAUGE 2) SHOWING NEAR APPROACH OF PIPE LINE TO HYDRAULIC GRADIENT. (PIPE NO. 31.)

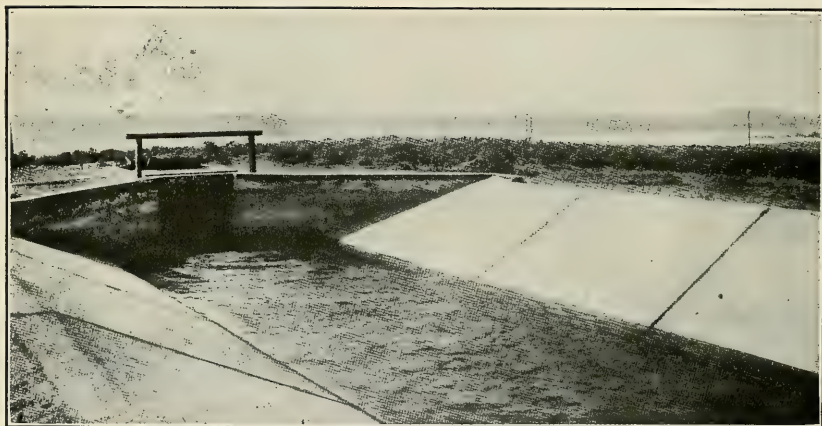


FIG. 2.—OUTLET STRUCTURE, PUMPING LINE OF PASCO RECLAMATION CO., WASHINGTON. (No. 33.) Discharge measured by rod floats in this concrete section.



FIG. 3.—ALIGNMENT AND PROFILE OF SIPHON, BURBANK CO., WASHINGTON. (No. 39.)

although the observations show that the capacity of the pipe is 10 per cent below the discharge computed by the new formula.

No. 19, Expt. S-10, 14-inch Jointed Machine-Banded Douglas Fir Pipe, Congdon Orchards, North Yakima, Wash.—About 1 mile of 14-inch pipe conveys water from the Yakima Valley Canal to the Congdon Orchards. A reach 1,251.7 feet long was chosen near the lower end. A mercury manometer was used as gauge No. 1 and a water column as gauge No. 2. The velocity was determined with fluorescein. The color was injected at gauge No. 1 and appeared at a 4-inch hydrant about 100 feet below gauge No. 2. The capacity of this pipe is about 4 per cent less than as computed by the new formula.

No. 26, Expt. S-13, 18-inch Continuous-Stave Redwood Siphon Pipe, Yakima Valley Canal Co., Washington.—Irrigation water is conveyed across two depressions between open reaches of canal by means of a redwood siphon of the continuous-stave type, built in the winter of 1913-14. Thus the pipe had been in use but a few months at the time of the test. It is buried about 3 feet in sandy and gravelly soil. Blow-off valves are located at the low points, while a valve allows the escape of air at the one summit on the line. Gauge No. 1, a mercury manometer, was located 279.3 feet from the inlet. Gauge No. 2, a water column, was located 1,787.5 feet from gauge No. 1 and 19.7 feet from the outlet. The nominal size of the pipe was accepted. The velocity within the pipe was determined with fluorescein. It was not practicable to vary the velocities through the pipe, but so far as two observations can be accepted the capacity of the pipe is 18 per cent greater than the discharge computed by the new formula. Some excess is to be expected, as newly planed redwood is very smooth and the pipe was so new that material deposits of silt were unlikely.

No. 27, Expt. S-7, 18-inch Jointed Machine-Banded Douglas Fir Siphon Pipe, Burbank Co., Washington.—Irrigation water from Snake River is carried over a swale between open sections of a small ditch by means of an inverted siphon. This pipe was laid during February, 1913. The top of the pipe is about 18 inches below the surface of very gravelly, open soil. However, the pipe surface is protected with a heavy coating of asphalt, so that the wood appears to be perfectly sound. The maximum head is only about 14 feet. Water columns were used at both ends of the reach tested. Gauge No. 1 was located 67.1 feet from the inlet while gauge No. 2 was located 1,479.1 feet from gauge No. 1 and 7.6 feet from the outlet. The nominal size of the pipe was accepted as correct. For each run the velocity within the pipe was determined through fluorescein tests by taking the mean velocity of five batches of color. The pipe is straight in horizontal alignment and has no summits in the vertical plane. For all practical purposes it may be considered straight from the fact that the low point is but 14 feet below the hydraulic gradient, in a total distance of 1,553.8 feet. At no point was there any indication of leakage, but there was no way of determining the interior condition of the pipe. It is used for irrigation about seven months of the year, but is kept full all winter. This probably accounts for the absence of leakage. The water as pumped from Snake River contains some sand, but all of the heavier particles have settled to the bottom of the canal before reaching the siphon, which is some distance from the stream. For this reason there is small likelihood of a deposit at the low point of the siphon, although the two observations taken indicate that the capacity is 6 per cent below the discharge computed by the new formula.

No. 29, Expt. S-2, 24-inch Jointed Machine-Banded White Pine Pipe, Butler Water Co., Butler, Pa.—Municipal water for Butler, Pa., reaches a pumping plant near the city by gravity flow through a 24-inch pipe line laid in 1907. This pipe is 5 miles long from Boyds Town Reservoir to a settling tank. The maximum static head is about 67 feet. The last half mile is a cast-iron pipe, while the rest is a white pine machine-banded wood pipe. As there was considerable leakage throughout most of the wood pipe a straight reach of the latter 1,357.7 feet long was chosen

well toward the juncture with the cast-iron pipe, which was considered tight. This fact permitted a close determination of the pipe's discharge by the rise of water in the settling tank (Pl. I, fig. 3), which is 50 feet in diameter, with vertical sides. Corrections were made for baffle walls and other displacement. The surface of the water in the tank was taken at 1-minute intervals with a plumb bob and steel tape. Mercury manometers were used at both ends of the reach. During any one run of water the mercury columns fluctuated but a few thousandths of a foot. The pipe is buried about 2 feet deep and is slightly elliptical. The mean of the areas of 10 pieces of pipe remaining from construction was taken as the area of the water section. Nothing is known regarding the interior of this pipe, but the observations indicate that the capacity is 5 per cent less than the discharge computed by the new formula.

No. 30, Expt. S-1, 24-inch Jointed Machine-Banded White Pine Pipe, Norfolk County Water Co., Va.—Water for domestic use in the territory in Norfolk County, Va., is pumped through 9 miles of 24-inch Canadian white pine machine-banded pipe from the Cadillac Pumping Plant to the plant in Princess Anne County. The pipe was laid during 1912 in lengths of from 3 to 12 feet. It is buried from 18 inches to 4 feet in sandy soil. The wood where bored for the manometers was sound, but the superintendent of the plant stated that there were several leaks in the line. This pipe is in use throughout the year. The reach tested is free from either horizontal or vertical curvature. It is 1,077.5 feet long, beginning about 100 feet below a gentle curve and extending to a point near the second pumping plant, where the pipe discharges over a rectangular weir into a concrete reservoir. The absence of moist ground indicated that there were no leaks on the reach tested, but the interior of the pipe was partly choked by a spongy growth. The velocity of water in the pipe was found by fluorescein tests. The discharge was determined by hook gauge readings for head on the weir shown in Plate I, figure 2. No correction is necessary for velocity of approach toward the weir, but the conditions of contraction are not quite standard. Mechanically the weir is well constructed and the discharge was not more than 2 per cent in error, in the estimation of the writer. The mean cross-sectional area of the interior of the pipe was determined by dividing the discharge as found above by the velocity as shown by the color. This area was 2.831 square feet, while the nominal area of a 24-inch pipe is 3.142 square feet. Loss of area was for the most part caused by the dense blanket of spongy growth adhering to the lower third of the circumference. As near as the writer could determine from the outlet end of the pipe, the rest of the perimeter of the pipe was smooth. With the above assumptions as to the true area of the pipe, the capacity is indicated by the observations to be 7 per cent greater than the discharge computed by the new formula, but if the presence of the growth were not known and the nominal size of the pipe accepted as the true size, then the capacity would be considered equal to the discharge computed by the new formula.

No. 31, Expt. S-15, 24-inch Continuous-Stave Redwood Pipe, Ogden, Utah.—Water for municipal uses is conveyed through Ogden Canyon to a reservoir near the city in a 24-inch redwood pipe, originally laid in 1890. The use to which this pipe is subjected, of course, requires it to be wet throughout the year, which is a more favorable condition than that usually encountered in irrigation practice, where a pipe is used but six to eight months. On the other hand this pipe practically reaches the hydraulic grade line at some of the summits. (During tests by the writer the water column at gauge No. 2 extended but 1 foot above the top of the pipe.) Thus there is not sufficient head for thorough saturation, yet the pipe appears to be in fairly good condition. The very rugged topography of this canyon precludes the use of long tangents in either horizontal or vertical alignment. The reach chosen for test commenced at the pipe bridge over Ogden River near "The Hermitage," where a mercury manometer was located as gauge No. 1. Gauge No. 2, a water column (Pl. II, fig. 1), was placed 2,240.7 feet from gauge No. 1. Douglas fir staves had been used

in replacing some deteriorated redwood staves, and both gauges had been attached to the pipe through these because the harder fir appeared to give a tighter repair when plugs were inserted in the tap holes after the gauges had been removed. However, according to the superintendent of the line, that part of the pipe between the gauges was of redwood. The nominal size of the pipe was accepted as correct. The velocity was determined by injecting fluorescein at gauge No. 1 and timing its travel to an auxiliary tap on the same circumferential ring with gauge No. 2. Although the pipe was 24 years old the two observations at commercial velocities indicate its capacity to be 3 per cent greater than that computed by the new formula.

No. 37, Expt. S-4, 36-inch Continuous-Stave Douglas Fir Pipe Line, Pasco Reclamation Co., Washington.—The rolling ground in the vicinity of Pasco, Wash., does not furnish adequate support for an open canal. For this reason, and because of the sandy nature of the soil, water for irrigation is conveyed in pipes after settling in a reach of open canal where it has a very low velocity. Tests for loss of head were made on the 36-inch pipe shown in Plate IV, figure 2. Gauge No. 1 was placed about 800 feet from the intake and gauge No. 2 was located 2,516 feet farther on. The line abounds in gentle curves, both horizontal and vertical. Mercury manometers were used for both gauges. The nominal diameter of the pipe was accepted as correct. As all the water flowing in the canal entered this pipe, it was only necessary to measure this flow for discharge. This was done by weighted rod floats of such lengths that any one float just cleared the bottom throughout the reach on which it was used. This pipe was laid in the winter of 1909 and 1910. For the most part it is buried from 1 to 3 feet in light sandy soil. Exterior decay of the pipe indicated that it would have been better to place the pipe on the surface of the ground. The two observations taken at commercial velocities indicate that the capacity of this pipe is 15 per cent less than that computed by the new formula. The writer can not account for this. Velocities are so low in the feed canal that all sediment should precipitate before reaching the pipe.

No. 38, Expt. S-5, 36-inch Continuous-Stave Douglas Fir Discharge Pipe, Pasco Reclamation Co., Washington.—Water for domestic and irrigation use is lifted 107.2 feet vertically from Snake River to the canal-reservoir shown in Plate II, figure 2. All of the pumps feed one continuous-stave wood pipe 36 inches in diameter. This pipe, 893 feet in length, was built in 1909. Though at a rather sharp incline, the pipe is practically straight. Gauge No. 1, a mercury manometer, was located 335 feet from the pumps, while gauge No. 2, a water column, was located but 20 feet from the outlet shown in the plate and 538.1 feet from gauge No. 1. The pulsation due to the pumps was evident in the mercury columns, but at gauge No. 2 their effect was hardly noticeable, even in the water column. The nominal diameter of the pipe was accepted as correct. The discharge was measured with weighted rod floats in the concrete section of open canal shown in the plate. These were of such length that they barely cleared the bottom of the channel. It was not practicable to vary the discharges through this pipe. The two observations taken at the commercial velocities indicate that the capacity of this pipe is about 13 per cent below the discharge computed by the new formula.

No. 39, Expt. S-8, 38.13-inch Continuous-Stave Douglas Fir Siphon Pipe, Burbank Co., Washington.—Irrigation water from the Snake River is conveyed across a wide swale in section 16, township 8 north, range 31 east, by means of a continuous-stave siphon 6,170.4 feet long, built in February, 1913 (Pl. II, fig. 3). This pipe is 38.13 inches in diameter, as determined by measurements of outer circumference throughout its length and by measurements of stave thickness. It is supported on cradles on the surface of the ground and appears to be in perfect condition. During the colder months water is withdrawn and the ends are plugged. Irrigation continues about seven months each year. The pipe is straight in horizontal alignment, while the vertical curves are so gentle that for all practical purposes they are

straight. There is one summit, as shown by the view. The maximum head is 74 feet. Water columns were used for both gauges. Gauge No. 1 was located 88.8 feet from the inlet. Gauge No. 2 was located 5,965.9 feet from gauge No. 1 and 115.7 feet from the outlet. Velocity within the pipe was determined by fluorescein tests, the mean time of travel of five batches of color being accepted. Levels were determined by static head; that is, on one visit to the pipe it happened that no water was running, so simultaneous readings at both gauges, taken 10 seconds apart for 1 minute, gave a true water level. The extremely slow fall of the water surface throughout these readings indicated that the leakage was negligible, which fact was also apparent to the eye. As well as an examination of the pipe outlet would disclose, the pipe was clean and smooth on the interior, though an examination of the long, low stretch across the marshy bottom of the swale might have shown deposits. The writer does not believe this likely, however, for the reason that the water flows for about 6 miles in open channels at comparatively low velocities before reaching the intake, and in these channels the heavier sand would have precipitated, leaving the water little more than clouded. The one observation at the commercial velocity indicates the capacity of this pipe to be about 10 per cent greater than that computed by the new formula.

No. 40, Expt. S-6, 40-inch Continuous-Stave Douglas Fir Siphon Pipe, Burbank Co., Washington.—Irrigation water is conveyed across a depression between two sections of open channel by a continuous-stave siphon, built in December, 1912, along the west side of section 6, township 8 north, range 31 east. This pipe was constructed on the surface of the ground and supported on cradles. At the time of these experiments, therefore, it was in its second irrigation season. As shown by the profile in Plate III, figure 1, there is one summit on the reach tested, but as this is protected by a standpipe, there was probably no air accumulation at the summit at the time of this test. Although the pipe is about 2,900 feet long, a reach 927.4 feet long was chosen near the outlet end for the reason that there is a diversion from the lowest point of the pipe. Gauge No. 1, a mercury manometer, was located 1,049.6 feet above the outlet and gauge No. 2, a water column, was located 122.2 feet above the outlet. The water divided in the outlet structure, flowing in two directions, one stream continuing in an earth channel and the other in a concrete-lined channel. The discharge in the pipe was determined by the sum of the flows in these two channels, as measured by current meter. The nominal area of the pipe was accepted as correct. At velocities exceeding 2 feet per second, it was noticeable that sections of the pipe immediately following the sharpest vertical curves vibrate about 1 inch, vertically, upon the cradles. This emphasizes the necessity for securing anchorage at bends. The two observations taken at commercial velocities indicate the capacity of this pipe to be about 3 per cent greater than that computed by the new formula.

No. 42, Expt. S-9, 48-inch Continuous-Stave Redwood Siphon Pipe, Cowiche Siphon, Yakima Valley Canal Co., Washington.—Water for irrigation is conveyed across Cowiche Canyon, about 4 miles from North Yakima, Wash., in a redwood siphon built in January, 1914. (Pl. IV, fig. 1.) Gauge No. 1, a mercury manometer, was located 67.3 feet from the inlet (Pl. III, fig. 2), while gauge No. 2, a water column, was located but 7.6 feet from the outlet. The inlet to the pipe is at the bottom of a concrete well about 10 feet deep. Subsequent tests to determine entry losses showed that much air was entrained and carried into the pipe, but no influence of air was apparent at gauge No. 1, which was attached to the pipe at the mid-point of its left side. From the intake to gauge No. 1 the pipe is straight. This is likewise true of the pipe for about 100 feet before gauge No. 2 is reached. For the balance of the distance between gauges the pipe is virtually one long vertical curve, as it is under a maximum head of about 100 feet and the total length is but 962.3 feet. The pipe has but one gentle bend in horizontal alignment. For each of the several runs made with different velocities in this pipe fluorescein was timed from inlet to outlet, the

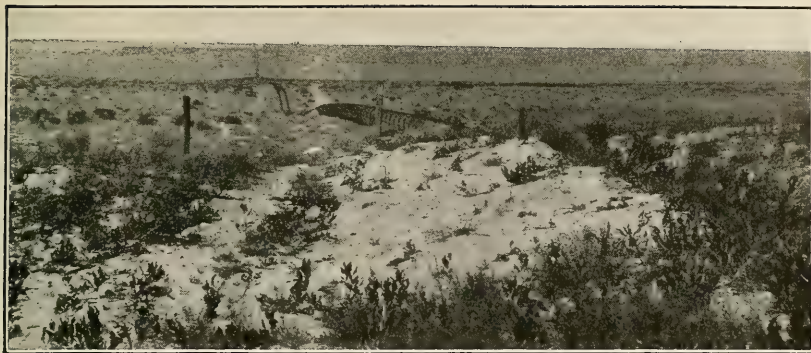


FIG. 1.—ALIGNMENT AND PROFILE OF SIPHON, BURBANK CO., WASHINGTON. (No. 40.)

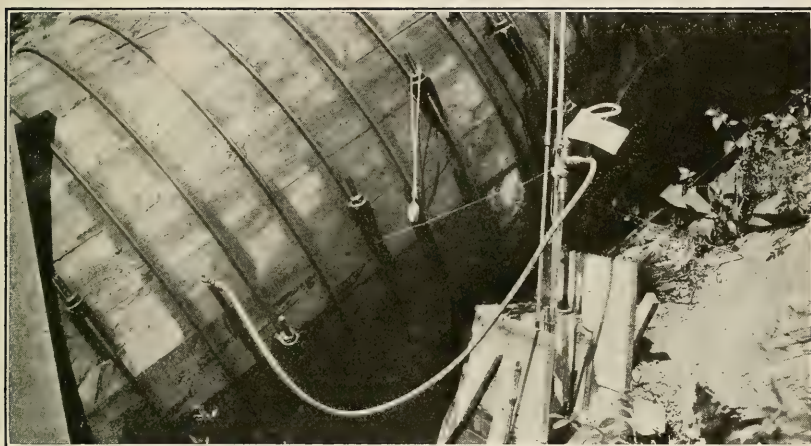


FIG. 2.—MERCURY MANOMETER (GAUGE 1) ATTACHED TO SIDE OF COWICHE SIPHON (No. 42), YAKIMA VALLEY CANAL, WASHINGTON.

See note on figure 1, Plate IV.

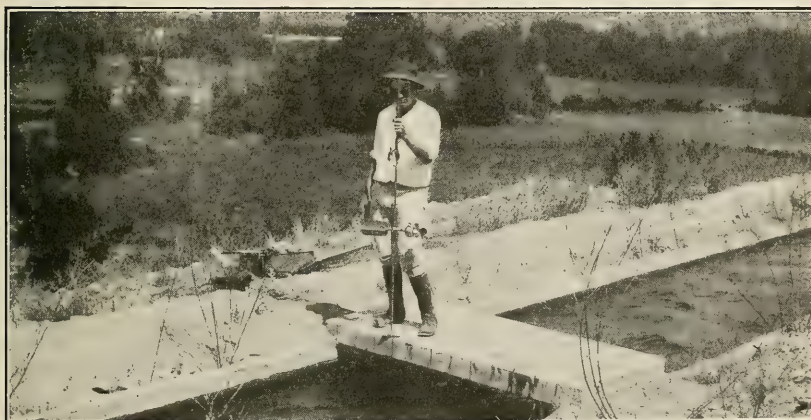


FIG. 3.—CURRENT METER STATION BELOW OUTLET TO PIPE NO. 42.

A concrete slab, marked every 0.5 foot.

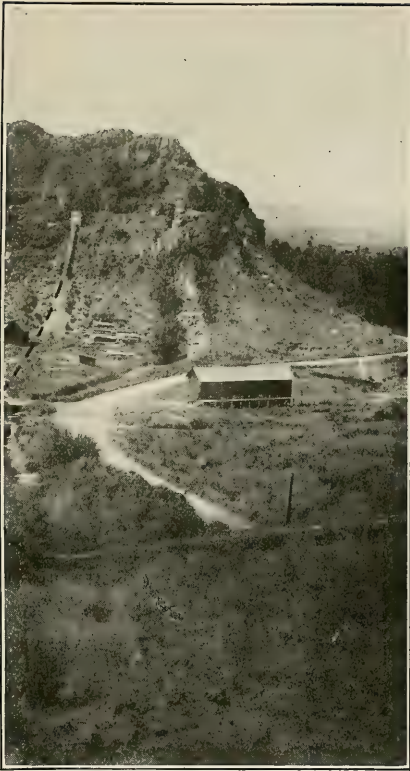


FIG. 1.—COWICHE SIPHON (No. 42), YAKIMA VALLEY CANAL CO., WASHINGTON.

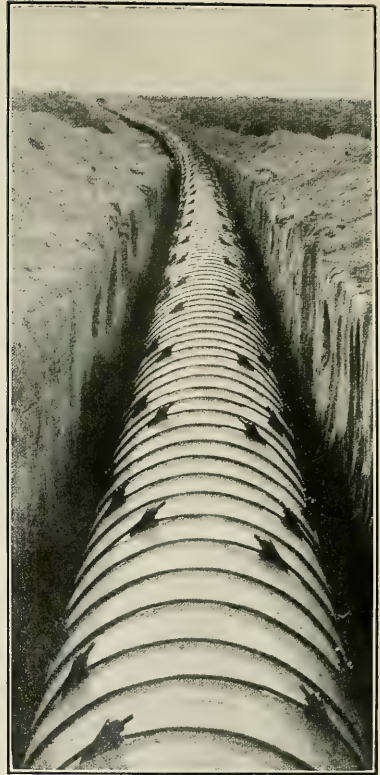


FIG. 2.—MAIN LINE, PASCO RECLAMATION CO., WASHINGTON (No. 37).
TYPICAL ALIGNMENT AND PROFILE.

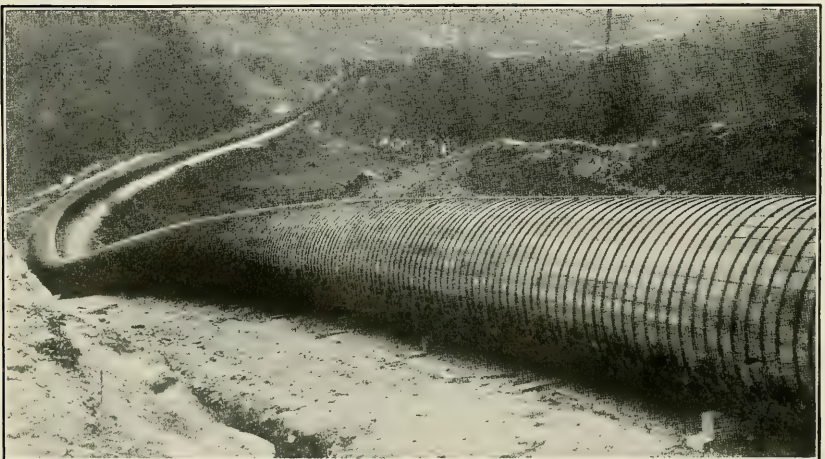


FIG. 3.—TRUNK LINE, MOHAWK HYDRO-ELECTRIC CO., NEW YORK (No. 50). TYPICAL ALIGNMENT AND PROFILE.



FIG. 1.—TRUNK LINE, SALMON RIVER POWER CO., NEW YORK. TAKEN ON REACH TESTED.
Typical alignment. Straight in profile. (No. 51.) See figure 2.

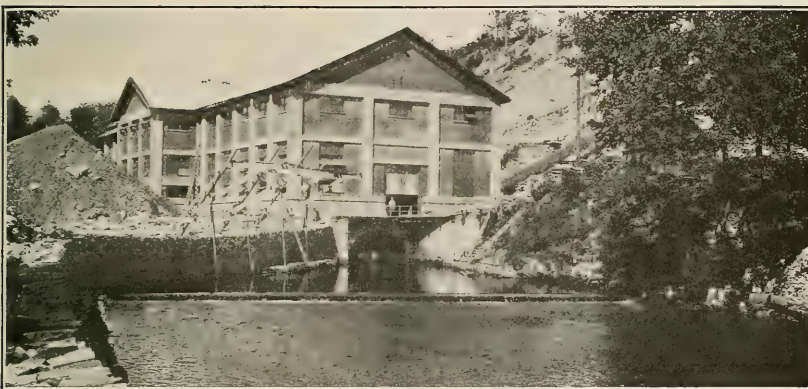


FIG. 2.—SUBMERGED WEIR BELOW POWER HOUSE, SALMON RIVER POWER CO. NEW YORK.
Discharge measured by calibrating weir. (No. 51.) See figure 1.

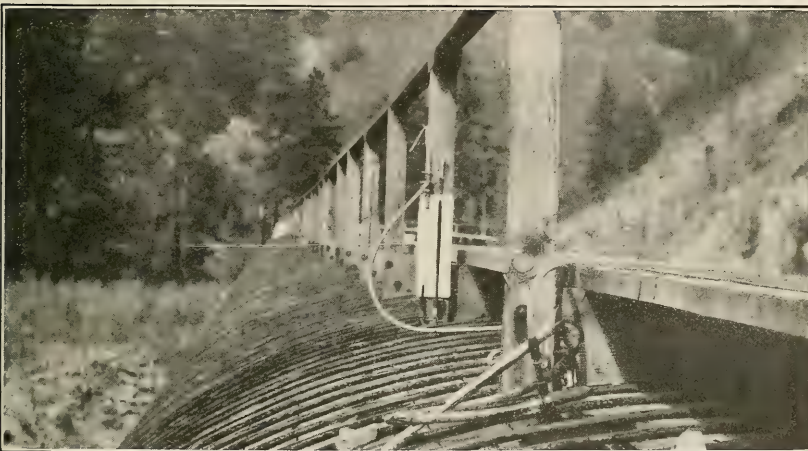


FIG. 3.—MERCURY MANOMETER AND FLUORESCIN GUN (GAUGE 1) ON 13½-FOOT PIPE
OF NORTHWESTERN ELECTRIC CO., WASHINGTON. (No. 52.)

mean velocity of four or five batches of color being accepted as the mean velocity of the water within the pipe for that particular run. Many of these color tests were checked by current meter measurements made by the two-tenths and eight-tenths depth method at the meter station shown in Plate III, figure 3. This station is in the concrete flume about 70 feet below the outlet from the siphon. The agreement between the two methods is shown in Table 1. As this pipe had been in use but a few months the interior was probably in excellent condition. The maximum discharge of the pipe necessitates a mean velocity of about 5.5 feet per second, so that it is probably scoured quite clean and smooth at all times. The capacity of the pipe was about 15 per cent greater than that computed by the new formula.

No. 50, Expt. S-16, 78-inch Continuous-Stave Douglas Fir Pipe,¹ Mohawk Hydro-Electric Co., Ephratah, N. Y.—The power house of the Mohawk Hydro-Electric Co., near Ephratah, is supplied with water by a trunk line of about 2½ miles of 78-inch stave pipe from the reservoir, Peck Lake, to the surge tank. (Pl. IV, fig. 3.) From the tank a stave pipe 96 inches in diameter extends to a point 1,460 feet distant, where the pressure head is 160 feet. It here joins a steel pipe of the same diameter, which completes the additional distance of a few hundred feet to the turbines. The writer conducted a series of tests on a reach of the 78-inch pipe 2,650 feet long. The lower end of this reach was about 1,000 feet above the surge tank. The whole line abounds in gentle curves, both horizontal and vertical. The pipe, built in 1910, was 5 years old at time of test. It is full of water throughout the year and is not protected against freezing, being so placed that some portions are completely buried and some completely exposed. Although extremely cold weather is experienced in this part of New York, the wood appears to furnish sufficient insulation. The peak load demands a velocity in this 78-inch pipe of less than 7 feet per second. This velocity and the fact that water comes from a reservoir that should act as a settling basin probably guarantees a pipe free from sediment. Several minor leaks were found on the reach tested. These are mostly at ends of staves where no additional bands were placed, and the pressure has bent outward the end of the stave farthest from the support of a band, the bend, of course, occurring under the last band. Whether the elastic limit of the wood had been exceeded and the fiber torn could not be ascertained, but the condition was such as to emphasize the desirability of confining all the joints in a stave pipe to a zone a few feet in length and placing extra bands throughout this zone. This of course does not apply to pipes under light pressures, say, 30 or 40 foot heads. Velocities within the pipes were determined directly with fluorescein for observations 1, 2, 3, 4, 7, 8, 9, and indirectly by comparison with the rating curve of the concrete channel forming the tailrace, for observations 5 and 6. The tailrace was calibrated by means of six careful current-meter gaugings, and a rating curve was plotted showing the comparison between gauge heights in the tailrace and velocities in the 78-inch pipe. The comparison between color tests and meter tests is shown in Table 1. The agreement between the two methods is closer than is usually expected by experienced hydrographers. Mercury manometers were used at both gauges. Some trouble was experienced from freezing temperatures (tests were made the first week in April, 1915), but no trouble occurred from air in the pipe, as the intake is deeply submerged. The color was injected at gauge No. 1 and observed at a secondary tap in the pipe 1 foot downstream from gauge No. 2, the water flowing into a white-lined pan which reflected greenish color. The same general procedure was followed here as on the Altmar tests (No. 51). That is, simultaneous readings were made over a long period of time, on both manometers and on a hook gauge in the tailrace. When the records were brought together, periods of slight fluctuation might be selected and each of these called an observation. Some such method as this must be chosen when a power plant in commercial operation is tested, as no one knows just when the changes in load, and consequent changes in velocity

¹ Engin. Rec., Vol. 64, No. 22, Nov. 25, 1911, p. 627.

within the pipe, are to occur. The capacity of this pipe was 9 per cent less than the discharge computed by the new formula. From the fact that the inlet is from a reservoir, and because the curves are very gentle, experience indicates that this pipe should have a greater capacity for a given loss of head than the new formula would indicate, although it is true that the interior condition of the pipe was not known. Two air valves at summits and one blow-off at a low point occur within the reach tested. The air valves are boxed to prevent freezing.

No. 51, Expt. S-3, 144-inch Continuous-Stave Douglas Fir Power Pipe Line,¹ Salmon River Power Co., New York.—About 4 miles from Altmar, N. Y., on the bank of the Salmon River, is located an hydroelectric plant, constructed in 1913 and 1914 to carry a portion of the load formerly served by one of the big plants at Niagara Falls. Stillwater Reservoir is formed by a dam across the main channel of Salmon River about 2 miles above the power plant. A tunnel 600 feet long conveys water from the reservoir to the upper end of a continuous-stave Douglas fir pipe line 144 inches (12 feet) in diameter. (Pl. V, fig. 1.) At the end of 3,450 feet a taper transition section about 50 feet long leads into a similar pipe 132 inches (11 feet) in diameter. Tests were made on the 12-foot pipe. The portion of the pipe tested is without vertical curves, being laid on an even gradient. Practically the lower third of the pipe is buried. No leaks worthy of notice occurred throughout the pipe. The line had been in operation but a few months, and since the velocities were high (up to more than 8 feet per second), it probably was in perfect condition on the inside, although it was not feasible to ascertain this. The staves are 4 inches thick. Taps for the nipples were made by a $\frac{1}{8}$ -inch wood bit until the tip of the bit punctured the inside surface of the pipe. The nominal area of the pipe was accepted as its true area. After making these tests the writer made careful measurements of a still larger pipe built by the same company and found the true area extremely close to nominal area. The discharge of the pipe, from which the velocity within the pipe was obtained, was determined in the following manner: As shown in Plate V, figure 2, after the water passes through the turbines it falls over a submerged weir into a tail-race channel which in turn discharges into Salmon River about a quarter of a mile below the power house. A good meter rating could be obtained, as the mean velocity for the greatest discharge was but 3.25 feet per second. This velocity did not cause a turbulent condition in the channel, since the latter had a hard, flat rock bottom. The form of the weir and the conditions of velocity of approach are such that the writer did not feel justified in accepting the discharge as computed from any known weir formula. The velocity of approach, in particular, is an uncertain quantity, since the bottom of the channel slopes up from 20 feet deep at the power house to a mean of but 1.234 feet deep immediately above the weir crest, within a horizontal distance of 220 feet. The weir is 79.6 feet long with end contractions approximately suppressed. It is a concrete wall 18 inches thick, rounded over on top. It is not designed as a measuring weir but for the sole purpose of drowning the draft tubes for all discharges. This weir was calibrated by making four careful current-meter measurements with as many discharges from a bridge across the tailrace below the weir; and meanwhile reading a hook gauge in a stilling box 8 feet above the weir and a tape gauge 3 feet below the weir. The latter gauge reading had no bearing on the calibration but was taken for the purpose of securing more information concerning submerged weirs. The results of these measurements follow. The elevations are based on a bench mark with an assumed elevation of 10.000 feet.

¹ Eng. Rec., vol. 69, No. 24, June 13, 1914, p. 671.

TABLE 4.—*Simultaneous discharge, elevation of water surface above weir, elevation of water surface below weir, and head on weir.*

No.	Discharge.	Elevation above weir.	Elevation below weir.	Head on weir.
	<i>Second-feet.</i>	<i>Feet.</i>	<i>Feet.</i>	<i>Feet.</i>
1.....	106.6	8.752	7.77	0.515
2.....	446.1	9.539	(not taken)	1.302
3.....	724.9	10.123	9.62	1.888
4.....	749.6	10.172	9.62	1.937

The mean elevation of the weir crest, 8.237 feet, was based on readings with level and rod taken every 5 feet throughout its length. During measurement No. 1 the hook gauge remained constant. During No. 2 water rose 0.142 feet on the weir. During No. 3 water fell 0.020 feet on the weir. During No. 4 water fell 0.049 feet on the weir. The mean gauge reading was accepted were fluctuation occurred. Current-meter measurements were made by the two and eight-tenths depth method. As the load carried (and consequently the discharge of water at a power house) varies throughout the day, and since the discharge is controlled by the load (by means of governors), the following method of testing the 12-foot pipe for loss of head was adopted: The mercury manometers and the hook and tape gauges were read continuously throughout the morning and afternoon. A synchronous profile was then platted showing all gauge readings. From this profile periods of comparatively uniform flow were chosen and each of these periods was designated as an observation. These would necessarily vary in length of time. From the calibration curve of the weir the discharge for each reading of the hook gauge was taken and the mean of these discharges was assumed as the discharge which held throughout the observation. The capacity of this pipe was 2.4 per cent less than that computed by the new formula. Since the pipe was new, joints smooth, and the curvature gentle, the writer would estimate the capacity of this pipe to be greater than that computed by the new formula. Tests by all experimenters show similar cases where the observations indicate far different results than the conditions appear to warrant.

No. 52, Expt. S-14, 162-inch Continuous-Stave Douglas Fir Power Line, Northwestern Electric Co., Condit Plant¹ on White Salmon River, Washington.—About 2 miles above the mouth of White Salmon River is located the Condit Plant of the Northwestern Electric Co. Some 6,000 feet upstream a high diversion dam raises the water above the intake to the supply pipe line. This, said to be the largest wood-stave pipe in the world, 162 inches or $13\frac{1}{2}$ feet in diameter, is used to convey the waters of White Salmon River from the diversion dam to the surge tank, a distance of 1 mile. Within the surge tank is a structure that divides the water from the $13\frac{1}{2}$ -foot pipe between two 9-foot pipes with very little loss of head. Each of the 9-foot pipes serves 1 electrical unit in the power house. (Pl. XI, fig. 1.) About midway of the large pipe, upon which tests were made, is a bend of 83° with a radius of but 40 feet (less than 3 diameters). In the opinion of the writer, such a bend would cause an appreciable loss of head independent of the friction loss, and for this reason a reach of pipe was chosen between this bend and the surge tank. Mercury manometers were used for both gauges, the equivalent water column being just too high to be feasible. (Pl. V, fig. 3.) Gauge No. 1 was located on the zone of neutral velocities 209.9 feet from the bend. Gauge No. 2 was located 2,378.9 feet from gauge No. 1 and about 40 feet above the dividing tongue in the surge tank. During all of the runs the load carried by the unit served by the right-hand 9-foot pipe was held constant, all the fluctuation being thrown to the other 9-foot pipe. The time necessary for fluorescein to travel from gauge No. 2 through the constant-velocity pipe was determined by

¹ Eng. Rec., Oct. 11, 1913; Eng. News., vol. 70, No. 15, p. 685.

accepting the mean time of four batches of color traveling from that gauge to the outlet of this particular pipe in the tailrace at the power house. For each of the tests for loss of head for differing velocities, color was injected at gauge No. 1 and timed to the outlet of the constant-velocity 9-foot pipe. To determine the time necessary for the color to travel between gauges for any particular run the time it spent in the 9-foot pipe was deducted from the total. For each run of water two batches of color were timed immediately before and after the gauge readings, and the mean time obtained was accepted.

A NEW SET OF FORMULAS FOR THE FLOW OF WATER IN WOOD-STAVE PIPE.

So far as the writer has been able to ascertain, there have been two suggested modifications of existing formulas and three sets of formulas which were intended solely for use in the design of wood-stave pipes.

With the experiments before them, which have been underscored in Plate VII, Williams and Hazen in 1903 suggested the coefficient 120 in their general formula ¹ given on page 6.

In 1915 Andrew Swickard,² after writing, "It is quite apparent that n [in Kutter's formula] is not a constant for wooden pipe but a variable that varies directly with the size of the pipe," offered the following formula representing this variation of n ,

$$n = \frac{d}{30,000} + 0.0105 \quad (15)$$

This formula ascribes all variation in n to the change in diameter of the pipe, while the present paper shows quite clearly in column 10 of Table 2 and in Plate VI that this variation is also a function of the velocity. This latter fact has also been noted by Moritz and by Williams.

The first formula proposed for sole use in design of wood-stave pipe (see p. 6) was offered by C. H. Tutton ³ in 1899. Although not given wide publicity in this country and apparently not used to any extent here, Parker regards it with much favor, stating ⁴ in regard to general formulas for the flow of water in pipes that "the most useful formula seems to be the one given by Tutton."

In this work Parker unfortunately misquotes Tutton's data from that journal, giving as Tutton's formula for flow in wood pipes, $V = 140 R^{0.59} s^{0.58}$, instead of $V = 129 R^{0.66} s^{0.51}$. (See p. 6.)

In October, 1910, T. A. Noble published his own formula,⁵

$$Q = 1.28 D^{2.58} H^{0.585} \quad (16)$$

which may be compared with formulas 11 and 14, pages 6 and 7. This formula was not given the publicity it deserved and does not appear

¹ Hydraulic Tables, Williams and Hazen, New York, 2d ed., 1909, p. 8.

² The Design of Wooden Stave Pipe, Engin. and Contracting, Vol. XLIII, No. 1, p. 10.

³ Journal Assoc. Engin. Soc's., 23 (1899), p. 151.

⁴ The Control of Water, P. & M. Parker, New York, 1913, p. 427.

⁵ Wood Pipe, T. A. Noble, Pro. Pac. Northwest Soc. Engin., Vol. IX, No. 1, Oct., 1910.

to have been used to any great extent, probably for the reason that it was based on tests covering only a few pipes, namely, a 4-inch pipe tested by Noble and Harris, Adams's 14-inch and 18-inch pipes, Noble's 44 and 54-inch pipes, and the Ogden tests of 1899 on the 72-inch pipe (Nos. 20, 23, 41, 44, and 48, Tables 2 and 3, and Pl. VII).

In 1911 E. A. Moritz proposed the fourth set of formulas¹ (see p. 6) with the following qualification: "This formula is not recommended for adoption until more data are available and some of the uncertain points have been cleared up."

A fifth set of formulas is now offered by the writer, who has fully appreciated the inadvisability of extending the number of formulas already existing except as must be required by continued investigation. His own experiments, especially those on large pipes, when studied in connection with all previous data, would seem to supply convincing proof that a new formula is needed.

With the exception of formula 15 all of the formulas referred to are of the exponential type; that is, they are based on the fact that for any particular series of observations, if losses of head are plotted logarithmically as one set of ordinates and velocities as the other, the resulting points will lie more or less along a straight line. Such a straight line on logarithmic paper represents an equation of the form

$$H = m V^z \quad (17)$$

which, expressed for logarithmic study, may be stated

$$\log H = \log m + z \log V \quad (18)$$

where m is the intercept on the axis of H , for $V = 1$ foot per second and z measures the inclination of the line, being the tangent of the angle which it makes with the axis of V .

For a series of pipes of the same general characteristics but of varying diameters the values of m follow the general equation

$$m = K d^x \quad (19)$$

Substituting in formula (17)

$$H = K d^x V^z \quad (20)$$

This expressed logarithmically becomes

$$\log H = \log K + x \log d + z \log V \quad (21)$$

Smith's tests (No. 1) were made on a pipe too small for any irrigation usage and the graphic representation of the results, while

¹ Trans. Amer. Soc. Civ. Engin., 74 (1911), p. 442.

adding no significant information, would have required a far larger diagram than that presented here. With the exception of these tests, therefore, data were plotted for all known observations where records were sufficiently complete. The writer agrees with J. S. Moore¹ that—

In preparing a tentative formula for general use all complete data, which can be accepted as criteria for the loss of head in wood pipe, should be recognized in arriving at a conclusion.

However, in deriving the new formula, tests made on round wood-stave pipe only were considered, in view of the proposed use of such a formula. The comparatively close agreement between results by use of the new formula and by the Tutton formula, as shown by Tables 2 and 3, indicates that had the excluded tests been used they would not have materially changed the new formula, inasmuch as Tutton used only four series, all of which were excluded by the writer because they were on other than wood-stave pipes. The close application of Tutton's formula to stave pipe, as shown by the consistent agreement in pipes all the way from 4 inches to 144 inches in diameter, is a remarkable coincidence, since his base data included no stave pipes whatever and but one round pipe.

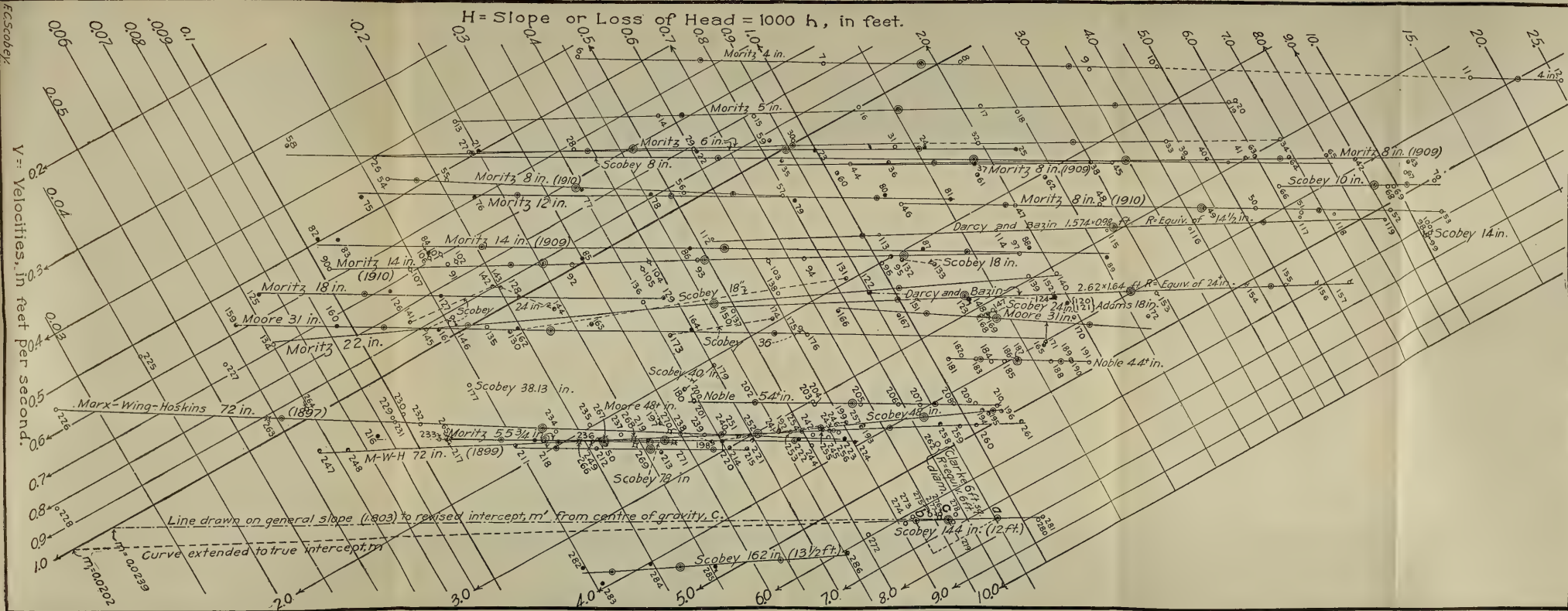
In deriving the new formula the following methods were used: After the observations had been plotted the diagram was used merely as a sketch, all slopes and intercepts being determined analytically. Where the test on any one reach of pipe included several observations the procedure observed was that used in the following example:

Take the writer's series 3 (Nos. 272-281, inclusive) on the 144-inch Altmar pipe. The center of gravity of all the points was first determined. The antilogarithm of the mean value of the logarithms of the respective velocities gave the velocity ordinate of the center of gravity. The slope ordinate of the center of gravity was found similarly. This point, *c*, shown by a dot within two circles (Pl. VI), divides all the plotted observations into two parts. The center of gravity of each of these parts was found by using only the observations within the zone of the part. These points, *a* and *b*, are shown by dots within single circles. Thus three points are found, all of which lie on the straight line representing the equation for that particular reach of pipe.

Let *c* = center of gravity of whole group; *a* = center of gravity of the part of the group above *c*; *b* = center of gravity of the part of the group below *c*; and let *c_v*, *a_v*, *b_v*, and *c_H*, *a_H*, *b_H*, be, respectively, the *V* and *H* coordinates of the above centers of gravity.

¹ Trans. Amer. Soc. Civ. Engin., 74 (1911), p. 470.





No.	V	H	log V		log H	
272	5.942	0.5144	0.7739	$\left\{ \begin{array}{l} \text{Sum}=4.7756 \\ \text{Mean}=.7959=b_v \\ \text{Anti-log mean} \\ \quad =6.250 \end{array} \right.$	9.7133	$\left\{ \begin{array}{l} \text{Sum}=58.8637 \\ \text{Mean}=9.8106=b_H \\ \text{Anti-log mean} \\ \quad =0.6466 \end{array} \right.$
273	6.127	.6426	.7873		9.8079	
274	6.190	.6154	.7917		9.7892	
275	6.312	.6938	.8001		9.8412	
276	6.436	.7237	.8086		9.8595	
277	6.516	.7155	.8140		9.8546	
278	6.693	.7700	.8256	$\left\{ \begin{array}{l} \text{Sum}=3.4915 \\ \text{Mean}=.8729=a_v \\ \text{Anti-log mean} \\ \quad =7.463 \end{array} \right.$	9.8865	$\left\{ \begin{array}{l} \text{Sum}=39.8249 \\ \text{Mean}=9.9562=a_H \\ \text{Anti-log mean} \\ \quad =0.9040 \end{array} \right.$
279	6.852	.7490	.8358		9.8745	
280	8.222	1.061	.9150		10.0257	
281	8.223	1.092	.9151		10.0382	
			Sum=8.2671		Sum=98.6886	
			Mean=.8267= c_v		Mean=9.8689= c_H	
			Anti-log mean=6.710		Anti-log mean=0.7393	

The center of gravity of the whole series thus comes at such a point that there are 4 points below and 6 points above c . Then

$$a_v - c_v = .0462, \text{ and } a_H - c_H = .0873;$$

$$c_v - b_v = .0308, \text{ and } c_H - b_H = .0583;$$

whence:

$$\frac{0.0462}{0.0308} = \frac{0.0873}{0.0583} = \frac{6}{4}$$

When the above ratios are in inverse proportion to the number of observations in the respective zones the three points found lie in the same straight line and approve the mathematical operations.

The exponent of V in formula 17 is the inclination of the line acb and is equal to the tangent of the angle formed by the curve and the axis of V . Thus

$$\frac{a_H - b_H}{a_v - b_v} = \frac{.1456}{.0770} = 1.891 = z. \quad (\text{See No. 51, column 17, Table 3.})$$

The intercept m is found as follows: Since $\log m = \log H - z \log V$ (from formula 18, p. 49), by using the coordinates of the center of gravity c

$$\log m = 9.8689 - 1.891 \times 0.8267$$

$$\log m = 8.3056, \text{ therefore } m = 0.02021$$

In the same manner the exponent of V for each of the pipes underscored in Plate VII was determined, being found to vary from 1.53 for No. 36 to 2.31 for No. 42. Any general law of variation in this exponent was not considered in their formulas by Moritz, Williams and Hazen, or the writer, although Hazen sees a tendency for the exponent to increase with the size of the pipe,¹ while Williams later offered the deductions mentioned on page 11. Simultaneous values of diameter and exponent were plotted on logarithmic paper.

¹ Trans. Amer. Soc. Civ. Engin., 51 (1903), p. 320.

As the exponent did not appear to vary in accordance with any particular law, but depended upon each individual pipe, the writer followed the authorities name above and derived one general value for this exponent. The method employed was as follows:

Obviously one observation on a particular pipe gave no data of value in determining the slope of a line. Two observations at about the same velocity contributed little more, but two observations at widely separated velocities gave enough information to indicate at least a tendency. Ten observations over a very short range of velocities did not give results as dependable as the same number over a greater range. Likewise ten observations, eight of which were close together and the other two well apart, did not contribute as much as the same number of observations evenly distributed throughout the range of velocities. With these general arguments and Plate VI as a basis, three men outlined a system for weighting the various exponents in the individual pipe formulas.

Four factors entered into this process: First, the number of observations; second, the distribution of the observations as shown by the distance between the centers of gravity of the upper and lower zones of observations; third, the extreme range of the observations on the chart; fourth, the actual range of the velocities. Usually the weight factor for the number of observations equaled the total number of observations, but some of the series showed an excessive evidence in restricted zones with fewer data in other zones. As an example of this, see No. 41. One observation within each half-second of velocity range received full weight. Each additional observation within the same half-second of range received an additional weight of half a unit. Thus the 11 observations in this series received a total rating of 8 for the number of observations. (See column 10, Table 3.)

The study of the data was made on 10-inch base logarithmic paper. Each inch of distance between centers of gravity of the upper and lower zones received a weight of 1 in the second factor. Thus, No. 41 was rated 1.6 in this factor. (See column 11, Table 3.)

Each inch of distance between the extreme observations also received a weight of 1 in the third factor. Thus, No. 41 was rated 2.8 in this factor. (See column 12, Table 3.)

Each one-half foot per second of velocity between the extreme observations also received a weight of 1 in the fourth factor. Thus No. 41 was rated 3 in this factor as the range of velocities extended from 3.5 to 4.8 feet per second, a difference of approximately 1.5 feet or the equivalent of 3×0.5 feet per second. The total weight for this pipe was the product of these four factors, the equivalent of

$$8 \times 1.6 \times 2.8 \times 3.5 = 125. \quad (\text{See column 14, Table 3.})$$

No pipe was permitted a greater weight than 1,000 in determining the exponent of V . If the product of the four factors exceeded 1,000 no additional weight over the 1,000 was assigned.

The writer is aware of the arbitrary character of this method of determining the exponent, but it was obvious that some system of rating must be assigned and the one used appears to give about the right weight to the various pipes when Plate VI is studied. The proof of the relative accuracy of this method is shown in Tables 2 and 3 where the mean of all observations entering into the derivation of the general value of the exponent agrees with the formula to within -0.33 per cent. (See foot of column 19, Table 2). The mean value for all the pipes entering into the derivation of the exponent agrees with the formula to within $+0.66$ per cent. (See foot of column 18, Table 3.)

Letting W_2, W_4, W_5 , etc., be the weights for Nos. 2, 4, 5, etc., in column 14, Table 3, and E_2, E_4, E_5 , etc., be the exponents of V in formulas for Nos. 2, 4, 5, etc. (column 17, Table 3), then

$$\frac{W_2 E_2 + W_4 E_4 + W_5 E_5 + \dots - W_{52} E_{52}}{W_2 + W_4 + W_5 + \dots - W_{52}} = z = 1.803$$

In deriving the values of the coefficient K and the exponent x , the writer has not pursued the usual practice. This is to plot and study logarithmically the various values of m (found in a similar manner to m on p. 51) and corresponding values of d as ordinates and abscissas, respectively.

The exponents of V in column 17, Table 3, vary within rather wide limits. The new general formula accepts a weighted mean value of this exponent, 1.803. Instead of using the values for m as taken from column 17, Table 3, the writer drew lines at the constant inclination 1.803 from the center of gravity of all the points in one series to the line where V equals 1 foot per second (the line for pipe No. 51 being shown in dot-dash in Pl. VI). This revised value of m for each series shown in Plate VI is found by the equation

$$\log m' = \log H - 1.803 \log V \quad (22)$$

(substituting 1.803 for z and transposing equation 18).

Again, taking No. 51 as an example:

$$\begin{aligned} \log m' &= 9.8689 - 1.803 \times 0.8267 \\ \log m' &= 8.3784 \\ m' &= 0.0239 \end{aligned}$$

By the method usually employed the value of m (0.0202) shown in the formula for No. 51, column 17, Table 3, would have been

used as derived on page 51. The reasoning which recommended revising the usual method follows:

In Plate VI the curves for the pipes of small diameters intersect the $V=1$ line. These intercepts give the values of m . Likewise, the lines drawn from the centers of gravity for these curves at the constant slope 1.803 give intercepts m' not far, as a rule, from m . Thus not very much difference appears for the smaller pipes; but out in the zones of curves for the larger pipes the average velocities are so much higher, and consequently the centers of gravity are so far from $V=1$, that the difference between m and m' is very marked. The revised method places all curves on the same footing; that is, the intercepts for the large pipes will have no more influence on the general formula than the intercepts for the small pipes. Using this method a line at the constant inclination 1.803 may be drawn through the point representing but one observation and a value of m' found that is of weight in determining the general formula, whereas this same point contributes nothing toward the determination of the exponent 1.803.

The values of m' for the various series are shown in column 16, Table 3. In order to derive the term Kd^x (formula 19), figure 4 was platted logarithmically with values of m' as ordinates and of d as abscissas.

The center of gravity of all the points is shown by the dot within two circles while the centers of gravity of the zones above and below this point are shown as dots within single circles. These three dots lie in the same straight line represented by the equation

$$m' = 7.68 d^{-1.17} = 0.419 D^{-1.17} \quad (23)$$

where 7.68 is the intercept on the line $d=1$ and -1.17 is the inclination of the curve to the horizontal axis.

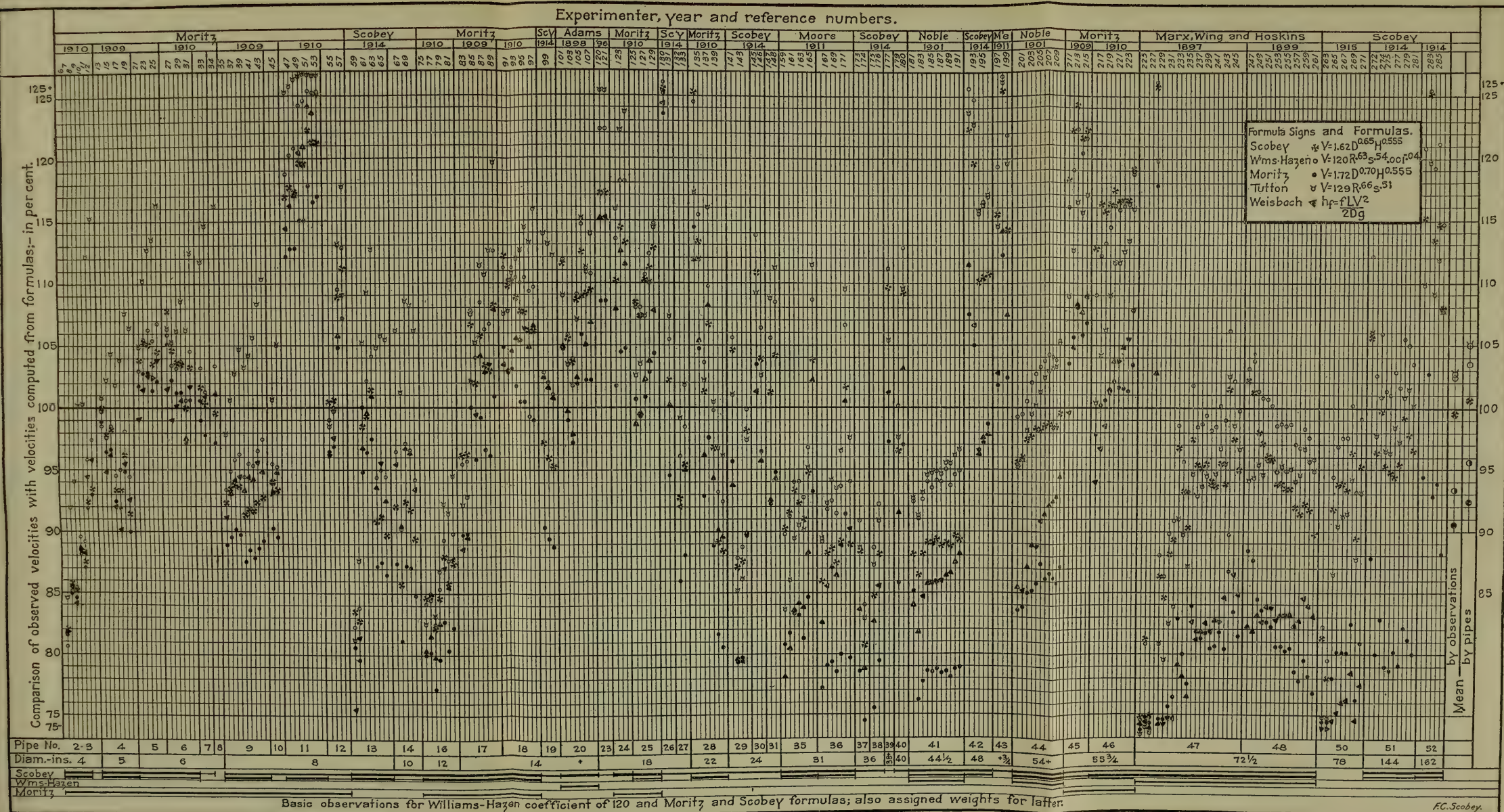
Substituting in the general formula (20, p. 49), the general equation is now evolved for wood-stave pipes, either jointed or of continuous-stave construction, based on the weighted average condition of all round stave pipe upon which accepted experiments have been made. This formula is

$$H = 7.68 d^{-1.17} V^{1.8} = 0.419 D^{-1.17} V^{1.8}$$

becoming

$$H = \frac{7.68 V^{1.8}}{d^{1.17}} = \frac{0.419 V^{1.8}}{D^{1.17}} \quad (12)$$

which is shown, with the related formulas, on page 7.

CHART SHOWING DEGREE OF CONFORMITY OF OBSERVED VELOCITIES OF WATER IN WOOD-STAVE PIPES TO CALCULATED VELOCITIES FOR GIVEN LOSS OF HEAD, BY SCOBEE, WILLIAMS-HAZEN ($C_w=120$), MORITZ, TUTTON, AND WEISBACH FORMULAS.



COMPARISON OF THE VARIOUS FORMULAS.

The comparison of the various formulas is shown in columns 19 to 23 and 18 to 22, inclusive, Tables 2 and 3, respectively, and graphically in Plate VII, which presents the following information:

First, a comparison in per cent of observed velocities to velocities computed by the Williams-Hazen formula (with $C_w=120$), the Moritz, Tutton, Weisbach, and the new formulas, for all accepted experiments on wood-stave pipes known to the writer where sufficient data are given.

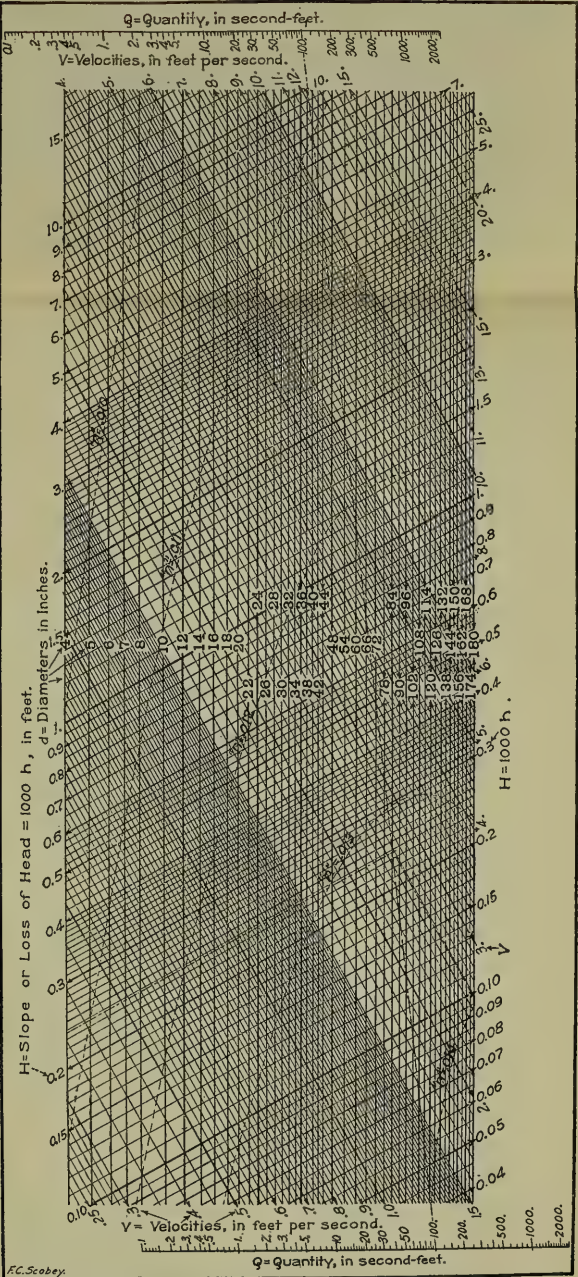
Second, the mean of the various percentages, awarding each observation the same weight; also the mean of the various percentages, awarding the average percentage for each reach of pipe the same weight. These items correspond with the footings under columns 19 to 23, inclusive, Table 2, and columns 18 to 22, Table 3.

Third, lines underscoring the observations used in deriving their formulas by Moritz and Scobey, and the observations leading Williams and Hazen to recommend a value of 120 as the coefficient to be used in their formula in the design of wood-stave pipe. (The Weisbach formula was derived from tests on metal pipes.)

Tutton apparently assigned the same weight to each series of tests, although he had but one observation on the Moon Island Conduit (No. 49) against five for No. 1, and eight for each of the other two (Nos. 22 to 33).

For the new formula double lines are used, the upper line denoting the observations used and the weight assigned (1, 2, or 3) in determining the general equation for m' , and the lower line denoting the observations used and the weights assigned in determining the exponent of V . (These lines correspond to the figures in columns 15 and 14, respectively, Table 3.)

As an example of the use of this chart, take observation No. 274 (run 9 on pipe No. 51). Near the top of the plate above the figures 274 (the reference number), *Scobey* is given for the experimenter and 1914 as the year. Under 274 it will be noted (as indicated by the cross) that the observed velocity (column 8, Table 2, 6.19 feet per second), is 0.1 per cent less (column 19, Table 2) than the velocity (6.20 feet per second, column 14, Table 2), as computed by the new formula for the same sized pipe with the same loss of head. Similarly the open circle shows that it is 5.9 per cent more than the velocity (5.83 feet per second) as computed by the Williams-Hazen formula (column 20, Table 2); the black dot shows it to be 17.2 per cent less than the velocity (7.48 feet per second) computed by the Moritz formula (column 21, Table 2); the winged circle shows it to be 0.8 per cent more than the velocity (6.14 feet per second) computed by the Tutton formula (column 22, Table 2); the fact that there are no



FC.Scobey.

LOGARITHMIC DIAGRAM FOR FLOW OF WATER IN WOOD-STAVE PIPE, BASED ON FORMULA $V=1.62D^{0.6}H^{0.55}$. SIMULTANEOUS VALUES OF n IN THE KUTTER FORMULA ARE GIVEN FOR COMPARISON.



nized as well as did Mr. Kutter himself, almost at the outset, that n was not to be considered a precise and unvarying constant, although it was more nearly so than any other constant before proposed." ¹

The fact that n does vary has been understood by hydraulicians specializing in work involving the Kutter formula, but notwithstanding this the tables and charts which have been accepted as standard have assigned values of n to certain degrees of roughness without reference to other conditions. The usual understanding regarding variation occurring in the value for n has been that n is less in large channels than in small ones, although the writer has not been able to show from a study of all available data that this variation is as great as suggested by Johnston and Goodrich².

In the case of wood-stave pipes an opposite effect is noted; that is, the value of n becomes greater as the value of R (which is directly proportional to the diameter) becomes greater. Referring to Plate VIII it will be noted that all of the straight lines are based on the new formula (13), page 7, while the n curves are determined in the following manner: To determine the curve for $n=0.012$, the intersections of the n curve with the diameter curves for various pipes are found and these give the locus for all pipes and velocities with $n=0.012$.

Each intersection is found by solving formulas 5 and 13 (pp. 6 and 7) as simultaneous equations, eliminating V , substituting a known value for D (from which the known value of R is found, as $R=\frac{D}{4}$) and solving for H , which is equal to 1000s in the Kutter formula. Note that the value of n increases for a given velocity as the size of pipe increases and that the value of n decreases for a given size of pipe as the velocity increases. These last two statements are borne out by a glance at the general trend of column 10, Table 2. Assume that Plate VIII, which is a graph of formula 13, page 7, correctly represents the flow of water in an average wood-stave pipe. This assumption is supported by the figures at the foot of columns 19 and 18 in Tables 2 and 3 respectively. Assume also that the n curves represent the simultaneous values of n for any position on the graph. Then the variations in the proper value of n to assume in the design of wood-stave pipe become so complicated that the Kutter formula had better be abandoned in favor of the exponential type of formula. This would leave the Kutter formula for its originally intended purpose, that of design of open channels, for which it is eminently fitted.³

¹ E. Ganguillet and W. R. Kutter, translated by Rudolph Hering and John C. Trautwine, jr. A General Formula for the Uniform Flow of Water in Rivers and other Channels, New York, 1907, 2d ed.

² C. T. Johnston and R. D. Goodrich. A Formula and Diagram for Determining the Velocity of Flow in Ditches and Canals. Eng. Rec., 64 (1911), No. 19, p. 542.

³ The Flow of Water in Irrigation Channels. Fred. C. Scobey, U. S. Dept. Agr. Bul. 194, p. 60.

EFFECT OF AGE UPON THE CARRYING CAPACITY OF WOOD-STAVE PIPE.

Some manufacturers and hydraulicians have contended that wood-stave pipe becomes smoother with length of use, and that therefore the capacity of the pipe increases with its age.

In order to study this question the writer prepared figure 5. This chart shows that, judging by available experimental data, there is no definite law between age and change in capacity, but unfortunately the results of but one test are accessible on any pipe older than 7 years. That pipe (No. 31, Ogden, Utah), although 24 years

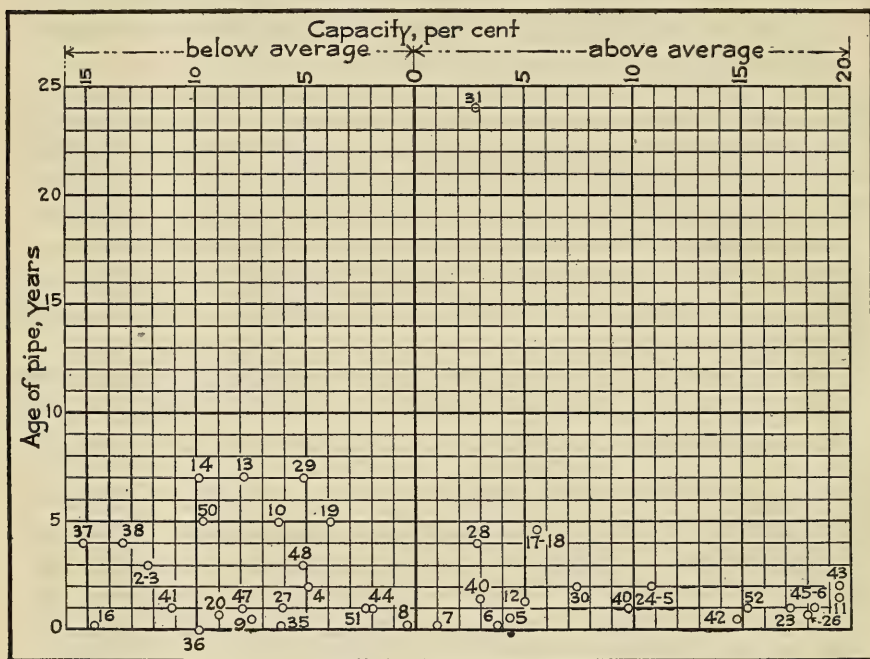


FIG. 5.—Diagram showing lack of relationship between age and carrying capacity. Numbers correspond with those in column 1, Tables 2 and 3. Ages taken from column 4, Table 3. Relative capacities taken from column 18, Table 3.

old at time of test, shows a capacity only about 3 per cent greater than the discharge computed by the new formula.

CAPACITY OF WOOD-STAVE PIPES.

In the following pages the design of wood-stave pipes is considered with reference to carrying capacity alone. Such structural features as thickness of staves, banding, cradles, etc., do not come within the scope of this paper.

The total loss of head necessary in the conveyance of a given quantity of water will be the sum of the velocity head, h_v ; the entry head, h_e ; and the friction head, h_f , or its equivalent per unit length;

less any velocity head, h_v' , that may be recovered as the water approaches the pipe outlet at a velocity relatively high compared with the velocity in the open water below the outlet chamber. This total may be expressed by the formula

$$H_E = h_v + h_e + h_f - h_v' \quad (21)$$

where H_E has the significance shown in figure 1 and h_v , h_e , h_f , and h_v' have the significance defined on page 3. The influence of gentle curves was included in the data upon which the formulas were based, so that an additional loss for slight bends or curves need not be considered in the design of the usual pipe on irrigation systems. If sharp bends can not be avoided then an additional loss of head must be anticipated. The results of such tests as have been made on bends in pipes are given in standard works on hydraulics.

VELOCITY AND ENTRY LOSSES.

In designing pipes of small diameter and great length, the losses due to velocity and entry heads, h_v and h_e , are so small compared with the friction loss that they may be neglected. Otherwise they should be included in the allowance for total lost head.

As a rule a wood-stave pipe line begins under one of four general conditions:

1. Intake chamber located in a reservoir, where the velocity of the water is practically zero. No taper or transition section between intake and pipe.

2. Intake chamber located on an open channel where there is an appreciable velocity toward the structure but where this velocity is not available because a bend or well at the intake practically dissipates the velocity head.

3. Intake chamber followed by a transition section in which the velocity is increased over that existing in the leading channel or reservoir. The outlet end of a pipe beginning under this condition is usually provided with a similar transition section.

4. The wood pipe but a continuation of another pipe of the same size but of concrete, steel, or other material. In this case there is little or no loss due to entry or velocity, the only factor introduced being the change in friction head due to change of material.

In conditions 1 and 2 it is best to consider the water above the intake as at rest. From this state of rest velocity must be created and increased to the mean velocity, V , existing in the pipe. The head, h_v , necessary to create a given velocity is shown in column 2, Table 5. The entry loss will be from $0.5 h_v$ where the pipe of standard size begins at a headwall and is without bell or taper mouth, to about $0.25 h_v$ for a rounded intake, and $0.05 h_v$ for a bell-mouth intake. Many of the structures built by the United States Reclamation

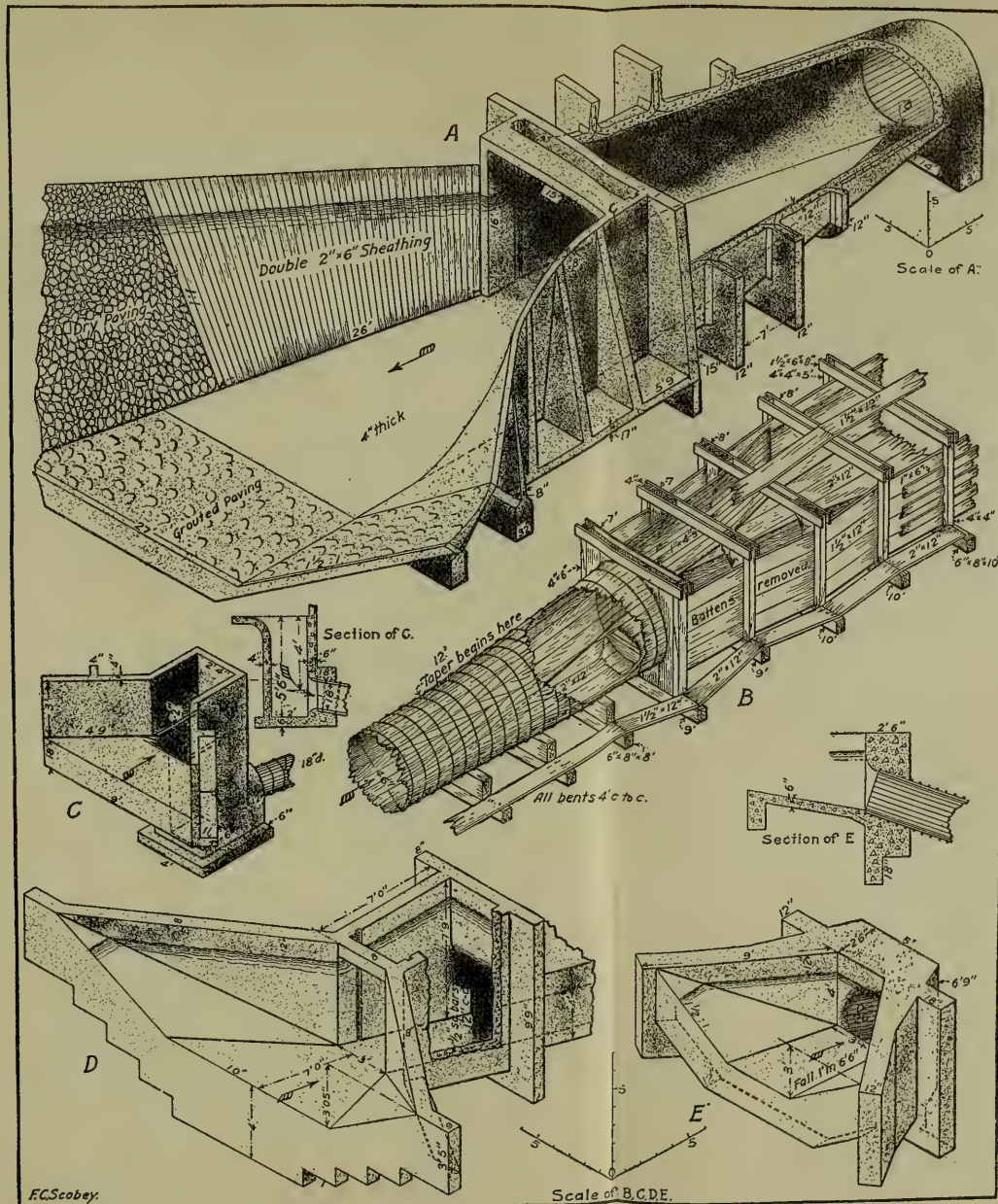
Service were designed with the entry loss taken as half the velocity head, even though there were more or less rounding and taper in the intake structures. In Table 5, column 3, is shown the amount of entry loss when taken as half the velocity head (column 2); and the sum of the entry and velocity losses is shown in column 4.

TABLE 5.—*Mean velocity in pipe, V , in feet per second; and head of elevation lost creating this velocity and overcoming entrance conditions, h_v+h_e , in feet.*

1 V	2 h_v	3 h_e	4 h_v+h_e	1 V	2 h_v	3 h_e	4 h_v+h_e
<i>Ft. per sec.</i>	<i>Feet.</i>	<i>Feet.</i>	<i>Feet.</i>	<i>Ft. per sec.</i>	<i>Feet.</i>	<i>Feet.</i>	<i>Feet.</i>
1.0	0.016	0.008	0.024	5.0	0.389	0.195	0.584
.2	.022	.011	.033	.2	.420	.210	.630
.4	.030	.015	.045	.4	.453	.227	.680
.6	.040	.020	.060	.6	.488	.244	.732
.8	.050	.025	.075	.8	.523	.262	.785
2.0	.062	.031	.093	6.0	.560	.280	.840
.2	.075	.037	.112	.2	.598	.299	.897
.4	.090	.045	.135	.4	.637	.319	.956
.6	.105	.053	.158	.6	.677	.339	1.016
.8	.122	.061	.183	.8	.719	.359	1.078
3.0	.140	.070	.210	7.0	.762	.381	1.143
.2	.159	.080	.239	.2	.806	.403	1.209
.4	.180	.090	.270	.4	.851	.426	1.277
.6	.202	.101	.303	.6	.898	.449	1.347
.8	.224	.112	.336	.8	.946	.473	1.419
4.0	.249	.125	.374	8.0	.995	.498	1.493
.2	.274	.137	.411	.2	1.045	.523	1.568
.4	.301	.151	.452	.4	1.097	.549	1.646
.6	.329	.165	.494	.6	1.150	.575	1.725
.8	.358	.179	.537	.8	1.204	.602	1.806

Where the usual types of inlet and outlet structures are employed, with but little construction and consequent expense incurred for conservation of entry and velocity heads it is recommended that the figures in Table 5 be used. In that case any influence on the total loss of head, derived from the rate of flow toward the intake as in condition 2, where water enters the pipe from an open channel, will introduce a small factor of safety for conservative construction. The same may be said of any slight recovered velocity head where the pipe discharges into an open channel.

In figure 1, Plate XII, probably the most common form of construction for both inlet and outlet of a wood-stave siphon is shown. In some cases taper staves are used in both inlet and outlet, so that the velocity is gradually increased in entering the pipe, thus reducing the entry loss. This construction classes the pipe under condition 3. The velocity is gradually decreased at the outlet, preserving the velocity head. The usual practice in this type of construction is to place the center of the pipe opening for the inlet chamber at or below the bottom of the leading canal. The pipe at the outlet is usually placed so that the top of the opening is slightly below the high-water line at full capacity.



SUGGESTIVE INLET AND OUTLET STRUCTURES FOR INVERTED SIPHONS.

The type of construction with a well having a rounded intake is shown in C, Plate IX. This type is generally used where the hillside is very steep just at the pipe intake or where a drop in grade line is included in the well structure.

In D, Plate IX, is shown a type of entrance structure for both round and square pipes quite frequently used by the United States Reclamation Service where moderate velocities (5 or 6 feet per second) only are to be considered.

The west Okanogan irrigation district (Washington) uses a general type like E, Plate IX, for both inlet and outlet structures. In the inlet structure shown the concrete rounds into the pipe opening, the center of which is level with the bottom of the canal.

The forms, reinforcement, and final entrance of a large siphon in Wyoming are shown in Plate XIII.

A pipe with both inlet and outlet tapering, such as condition 3, will have the maximum efficiency as it approaches a "Venturi tube with elongated throat," as described to the writer by D. C. Henny. Such a structure would have the sides of the inlet converge at the rate of about 1 in 5, while the transition section at the outlet would diverge at the rate of about 1 in 24. On such a pipe less than 5 per cent of the velocity head will be unrecovered, charging all losses other than friction to entry head.

The transition section usually includes part of the intake or outlet structure proper and also a short length of the wood pipe. On the Arkansas Valley conduit of the Colorado Fuel & Iron Co. there are 25 siphons of wood, incased in concrete.¹ The intake ends of these siphons taper at the rate of 1 inch per foot of pipe until the diameter at the opening is 1 foot greater than that of the main pipe. The inlet to one of these siphons is shown in figure 3, Plate XII.

This argument regarding conservation of velocity head and reduction of entry head is exemplified in the recently completed designs for a large siphon carrying water at a very high velocity at the Sun River crossing on the Sun River project of the United States Reclamation Service. The outlet structure is shown as A in Plate IX.

The water section in the leading canal has an area of 928 square feet with a velocity of 1.08 feet per second. By tapering wing walls and concrete intake structure the area at the upper end of the wood-stave pipe has been reduced to 50.3 square feet (96-inch pipe) and the velocity increased to 19.9 feet per second. By this time 6.14 feet of head of elevation has been devoted to building up a high velocity. Of course it is important that as much as possible of this velocity head be recovered at the outlet end.

¹ Frictional Resistance in Artificial Waterways. V. M. Cone, R. E. Trimble, and P. S. Jones, Colorado Sta. Bul. 194 (1914).

Throughout approximately the last 100 feet of wood pipe ending at a, Plate IX, tapering staves are inserted in the pipe until an elliptical section 12 feet wide and 9 feet high is reached at a. The area has been increased so gradually up to 84.82 square feet that, it is computed, 3.99 feet of velocity head have been recovered, the velocity meanwhile being reduced to 11.8 feet per second. Between b and c the transition section changes from an elliptical to a rectangular shape $13\frac{3}{4}$ feet wide by 10.6 feet high, with an area of 153.12 square feet. In this transition section the vertical walls and flat floor and roof begin at b with zero width, increasing to full width at c, the corners being rounded out in the concrete. The velocity is further diminished to 6.54 feet per second and the computations show an additional velocity head of 1.51 feet recovered. At the upper end of the canal leading from the structure the velocity is further reduced to 2.10 feet per second by enlarging the section, the additional recovered velocity head being computed as 0.59 feet. Thus of the 6.14 feet devoted at the inlet end to increasing the velocity, the computations show the recovery of all but the 0.05 foot, which is due to the difference in velocities in the channels above and below the structure. However, even with carefully designed transition sections the computations show an aggregate of 1.80 feet devoted to "entry head" at the various changes in cross section.

The outlet structure of the Similkameen Siphon of the West Okanogan Irrigation District, Washington, is also designed with a view to conservation of velocity head. This structure (B, Pl. IX) consists of a 46-inch stave pipe tapered in a length of 12 feet to a diameter of 57.5 inches, the pipe then discharging into a wooden flume. The most noticeable feature of the structure is the use of guide wings extending into the flume. These prevent a sudden enlargement of the cross section at the end of the pipe and tend to recover the velocity head. The floor of the flume is extended into the pipe to the point where the taper section begins, thus preventing contraction and consequent loss of head due to extension of the segment of the pipe below the floor line at the bulkhead. No attempt is made to secure watertightness in these guide wings, but the water is allowed to enter between the wings and the flume proper so that no pressure may be brought against the light wings. All tightness is secured at the bulkhead and in the flume proper.

Where a change is made in the size of pipe a long taper transition section is usually installed. In the Altmar pipe (No. 51) the diameter is changed from 12 to 11 feet. This change is so gradual that it can hardly be detected by the eye. In a similar way the Mabton pressure pipe (Nos. 43, 45, and 46) is reduced from $55\frac{1}{2}$ inches to $48\frac{3}{4}$ inches. Where changes in sectional area are made in this manner probably

the loss of head due to such change is negligible, the change in velocity head alone being appreciable.

Unless a tapered outlet structure is installed it will be best to consider all of the velocity head within the pipe as dissipated in impact and eddies due to the sudden enlargement of the sectional area in the outlet chamber. That is, for purposes of design recovered velocity head should not be counted upon.

During the season of 1915 the writer endeavored to secure information as to the amount of head lost between the surface of the water at the intake and a point 3 diameters down the pipe, charging such loss of head to velocity and entry losses jointly. Some of the pipes tested were of concrete and some of wood, but this difference did not alter the value of the information secured. The latter was meager, however, for the reason that designers have been ultraconservative in allowing for friction losses of head in the pipe; consequently the entrance in most cases is not submerged. The water from the canal rushes down the first reaches of pipe and in a very turbulent and air-charged condition finally fills the pipe.

Table 6 shows the results of such tests as could be made. These were incident to those made for the determination of friction losses in the pipe.

TABLE 6.—*Tests for loss of head at inlet of wood and concrete pipes.*

1	2	3	4	5	6	7	8	9	10	11
Test.	Diam-eter.	Mean velocity in pipe per second.	Loss of head, intake to gauge 1.	Loss of head per foot of pipe, gauge 1-2.	Length of pipe, 3D to gauge 1.	Total loss from 3D to gauge 1.	Loss between intake and 3D.	$h_v =$ velocity head for V, col. 3.	$h_e =$ entry head $= \frac{1}{2} h_v$.	$h_v + h_e$.
	<i>Inches.</i>	<i>Feet.</i>	<i>Foot.</i>	<i>Foot.</i>	<i>Feet.</i>	<i>Foot.</i>	<i>Foot.</i>	<i>Foot.</i>	<i>Foot.</i>	<i>Foot.</i>
1.....	8	3.51	0.039	0.0108	3.8	0.041	-0.002	0.191	0.095	0.286
2.....	8	3.56	.014	.0108	3.8	.041	-.027	.197	.097	.294
3.....	12	1.60	.021	.00126	7.0	.009	+.012	.040	.020	.060
4.....	12	1.60	.047	.00146	7.0	.010	+.037	.040	.020	.060
5.....	60	3.08	.125	.00054	65.0	.035	+.090	.150	.075	.225
6.....	60	3.03	.098	.00056	65.0	.036	+.062	.144	.072	.216
7.....	54	4.03	.498	.0015	12.8	.019	+.479	.254	.127	.381
8.....	54	4.02	.431	.0016	12.8	.021	+.410	.252	.126	.378

It is appreciated that this table is of but little assistance in the design of intakes, but it is offered as a start toward the collection of information on this subject. Except in the case of tests 1 and 2 the velocity of approach was indeterminate, due to changes in channel section and to eddying conditions. It will have served its purpose if it brings out the fact that close computations on entry and velocity head losses can be but approximate.

A hook gauge in a stilling box in the intake gave the water surface at that point, while the elevation of the top of the equivalent water column (see p. 22) at gauge No. 1, deducted from the elevation of

the water surface at the intake, gave the loss of head between the intake and gauge No. 1. These losses are shown in column 4. Column 7 gives the friction loss between a point 3 diameters down the pipe from the intake and gauge No. 1. This column is based upon the friction loss per foot within the pipe (column 5) multiplied by the number of feet (column 6) back from gauge No. 1 to the 3-diameter point. Column 4 less column 7 gives the computed loss of head (column 8) due to velocity and entry heads combined between the intake and the 3-diameter point. Theoretically column 8 should approximate column 11, which is the sum of columns 9 and 10, but in most cases the velocity of approach was sufficient to make the entries in column 8 much smaller than those in column 11.

Referring to these two columns: Tests 1 and 2 were conducted on a concrete pipe where the water entered a 16-inch standpipe from an 8-inch pipe and left the opposite side in an 8-inch pipe. The observations show that no head was lost within the standpipe. Tests 3 and 4 were on pipes in an installation similar except that the water left the standpipe in a 12-inch pipe at right angles to an 8-inch pipe through which it entered. Tests 5 and 6 were on the pipe shown in Plate XII, figure 3. Here the velocity of approach in the canal acted directly on the intake opening, greatly reducing the loss of head. Tests 7 and 8 were on a similar pipe, but in this instance the canal turned an abrupt right angle just before entering the pipe, causing a violently turbulent condition which probably introduced a large error in the observed head at the intake.

AIR IN PIPE.

In speaking of a pipe that did not show sufficient carrying capacity Moritz states:¹

Examination showed that air imprisoned in the pipe was causing the difficulty. This was overcome by inserting a $\frac{1}{2}$ -inch wrought-iron standpipe in the top of the pipe about 15 feet below the intake. In this way the air was, to all appearances, entirely removed, and the carrying capacity was raised to 1.54 cubic feet per second, an increase of about 60 per cent.

Pipes taking water directly from reservoirs are, of course, not subject to these troubles, the depth above the intake being, as a rule, sufficient to insure filling of the pipe with water alone.

Siphon pipes and, in even greater degree, pipe chutes are often reduced in carrying capacity by entrained air. In his investigations on wood-stave pipes the writer has observed that air troubles are minimized under the following conditions: (a) Low velocity in channel approaching inlet; (b) inlet end set well below the hydraulic gradient, as a rule with top of pipe at about same elevation as bottom of the canal above the inlet; (c) intake chamber designed to minimize eddies.

¹ Trans. Amer. Soc. Civ. Engin., 74 (1911), p. 435.

Moritz suggests the extensive use of air valves in some form. The best air outlet is probably a "chimney" rising above the hydraulic gradient. There should be several connections to the siphon, either normal to the pipe or, better, pointing slightly upstream. These may be independent of each other or all may connect to a common pipe extending along the top of the siphon, the upper end passing through the head wall of the intake chamber so that any water that blows out with the air will fall back into the pipe. The last connection should be at a lower elevation than the water surface in the outlet chamber so that, with a small discharge, the air entrained will be collected and passed off. As a rule low discharges entrain more air than does a full discharge, since the water rushes down the initial reaches of pipe in a turbulent condition. On the other hand, the upper air vents are necessary to care for air entrained and compressed during discharges approaching maximum capacity. These vents may be from 1 to 12 inches in diameter, depending on the size of the wood pipe, and should be so assembled that they may be taken apart, as *débris* collects in such vents and must be periodically removed. If excessive air troubles are present, a collecting chamber may be attached to the siphon at each vent, the air pipe being attached to the top of the chamber rather than directly to the siphon pipe.

FRICTION LOSSES.

The loss of head necessary to overcome internal resistances within the pipe is proportional to the length of the pipe but is independent of the static pressure in the pipe. That is, the loss necessary in the conveyance of a given quantity of water through a siphon pipe will be the same whether the low point is, say, 10 feet or 150 feet, below the hydraulic grade line, the other factors remaining unchanged. The influence of temperature upon the frictional resistances was found by Saph and Schoder to be considerable in small brass pipes but has not been studied in connection with tests on large wood pipes. It is doubtful whether the influence of temperature could be differentiated from that of friction alone in tests on large pipes in commercial service.

In order to determine the size of pipe and the loss of head necessary to overcome the frictional resistances in the conveyance of a given quantity of water, two estimate diagrams and a table have been prepared. Two examples of typical pipe problems are given. In these the use of the diagrams only is explained, as the table is considered self-explanatory. The factors of safety given below should be considered in each problem, as a study of Plate VII shows that an averaging formula, accepted literally, can not assure the desired discharge for a given loss of head.

FACTORS OF SAFETY.

A study of Plate VII shows that a general formula may be often 10 per cent, sometimes as much as 15 per cent, and in isolated cases 25 per cent, at variance with observed capacities for given losses of head. Likewise a study of the conditions holding in various pipes fails to disclose just when high or low relative carrying capacities are to be expected. However, the following factors of safety appear to be warranted:

Five per cent when only a rough approximation to the actual needs of the pipe is possible; when water enters the pipe from a settling reservoir and velocities in the pipe are so high that a clean-scoured condition will always be present inside the pipe; and also where conditions of operation are such that no penalties are attached to a slight insufficiency of carrying capacity.

Ten per cent when the above conditions for a very clean pipe are assured, but where penalties are attached to lack of capacity; or where no direct penalties are attached but silted waters and low velocities may permit deposits and growths of *Spongilla* or other vegetable life.

Fifteen per cent where rock ravelings may reduce the interior area of the pipe, or when penalties are attached and silted water or vegetable growth are likely to cause excess retardation of flow.

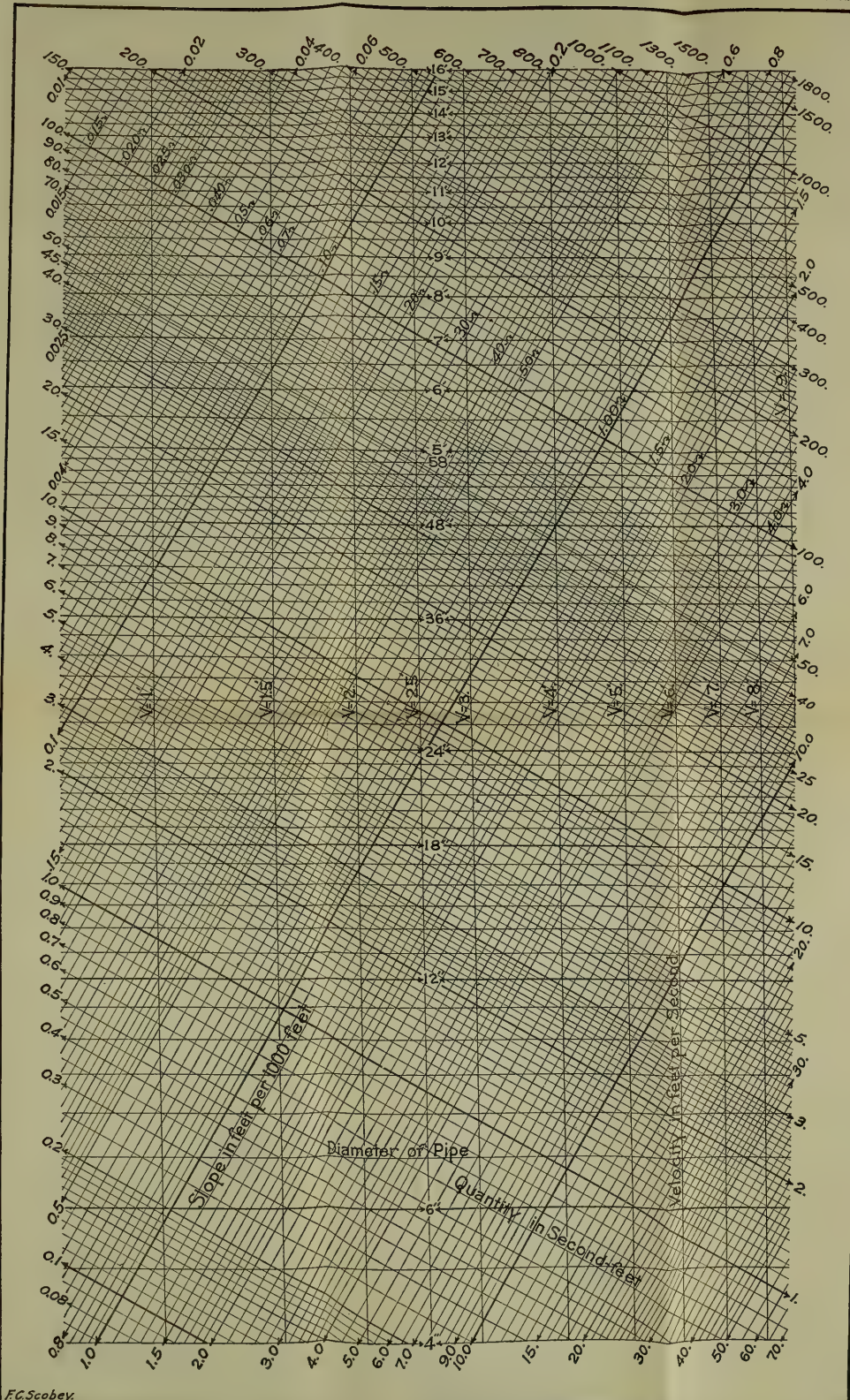
The designer may safely assume that the capacity of wood pipe will not change unless the pipe is subject to silting, ravelings, or vegetable growth. (See fig. 5, p. 58.)

ESTIMATE DIAGRAMS AND TABLE; SOLUTIONS FOR TYPICAL PIPE PROBLEMS.

1. An inverted siphon is required to convey 60 second-feet of water a length of 2,800 feet with an allowable total loss of head of 1.8 feet. Water has settled in a reservoir before entering the canal. No direct penalty has been attached for lack of capacity. Required, diameter of the pipe.

Allowing a 5 per cent overload as a factor of safety, the rated capacity will be $60 + 3 = 63$ second-feet. Since the velocity is not known, the entry and velocity head combined can not be determined at present. For preliminary figures, $2,800 \text{ feet} = 2.8 \times 1,000 \text{ feet}$; therefore $\frac{1.8}{2.8} = 0.642 = H$. Referring to Plate X,¹ enter diagram at 63 second-feet. Intersection of $Q = 63$ with $H = 0.642$ is about on the diameter line for 58 inches and at a velocity point of about 3.6 feet per second. Referring to Table 5, opposite $V = 3.6$ the combined

¹ Plate X was prepared by the writer from the new formula (No. 14, p. 7) in a manner similar to that first used by Schoder in Engineering Record, Sept. 3, 1904.



F.C. Scobey.

LOGARITHMIC DIAGRAM FOR USE IN DESIGNING WOOD-STAVE PIPE. BASED ON FORMULA: $Q = 1.272D^{2.5}H^{0.66}$.

Any point on the diagram gives simultaneous values of quantity, Q; diameter of pipe, D; loss of head per 1,000 feet, H; and velocity, V. For problems involving velocities less than 0.7 foot per second or more than 9.0 feet per second, see Plate VIII.



velocity and entry head is found to be 0.303 feet. Therefore, the final figures are $\frac{1.8-0.3}{2.8}=0.536=H$.

Again, referring to Plate X, at the intersection of $Q=63$ and $H=0.536$ the diameter of the required pipe is found to be 60 inches and the peak-load velocity to be 3.3 feet per second. The difference between the preliminary figure for combined velocity and entry heads and the final figure is not sufficient to warrant more trials.

2. A power trunk line from a reservoir to a surge tank to convey a peak load of 700 second-feet is required. The length of pipe will be 11.3 miles, the total loss of head under peak load shall not exceed 20 feet, and the value of head shall be sufficient to warrant a factor of safety of 15 per cent in designing. Required for comparison, the size of pipe for both a single and a double pipe line with the same loss of head.

The length of pipe is so great that velocity and entry head may be ignored.

One hundred and fifteen per cent of $700=805$ second-feet.

Eleven and three-tenths miles $=11.3 \times 5,280 = 59.664 \times 1,000$ feet.

$$\frac{20.0}{59.7}=0.335 \text{ feet per } 1,000 \text{ feet} = H.$$

Enter Plate X at $Q=805$. Intersection of $Q=805$ with $H=0.335$ is at $D=14.5$ feet and at $V=5$ feet per second. Thus a single pipe line 14.5 feet in diameter will convey the peak load at a velocity of about 5 feet per second.

To study the possibilities of a double pipe line, turn to figure 6. Enter at intersection of diameter 14.5 feet and relative capacity 1. From this point the left slanting line intersects relative capacity line $\frac{1}{2}$ on diameter line 135 inches or diameter line 11.25 feet. Thus twin lines each $11\frac{1}{4}$ feet in diameter will convey the given quantity of water with the same loss of head as will a single line $14\frac{1}{2}$ feet in diameter.

Pipe problems involving velocities less than 0.7 foot per second or more than 9 feet per second may be solved by the use of Plate VIII. With a straightedge join the two discharge scales at the given discharge. All points on the straightedge will now give simultaneous values of diameter, loss of head, and velocity. For instance, the dash-dot line representing 100 second-feet intersects the 84-inch pipe line on the H-line of 0.237 foot per 1,000 feet and on the V-line of 2.58 feet per second. Thus an 84-inch pipe will convey 100 second-feet of water at a velocity of 2.58 feet per second with a loss of head of 0.237 foot per thousand feet of pipe.

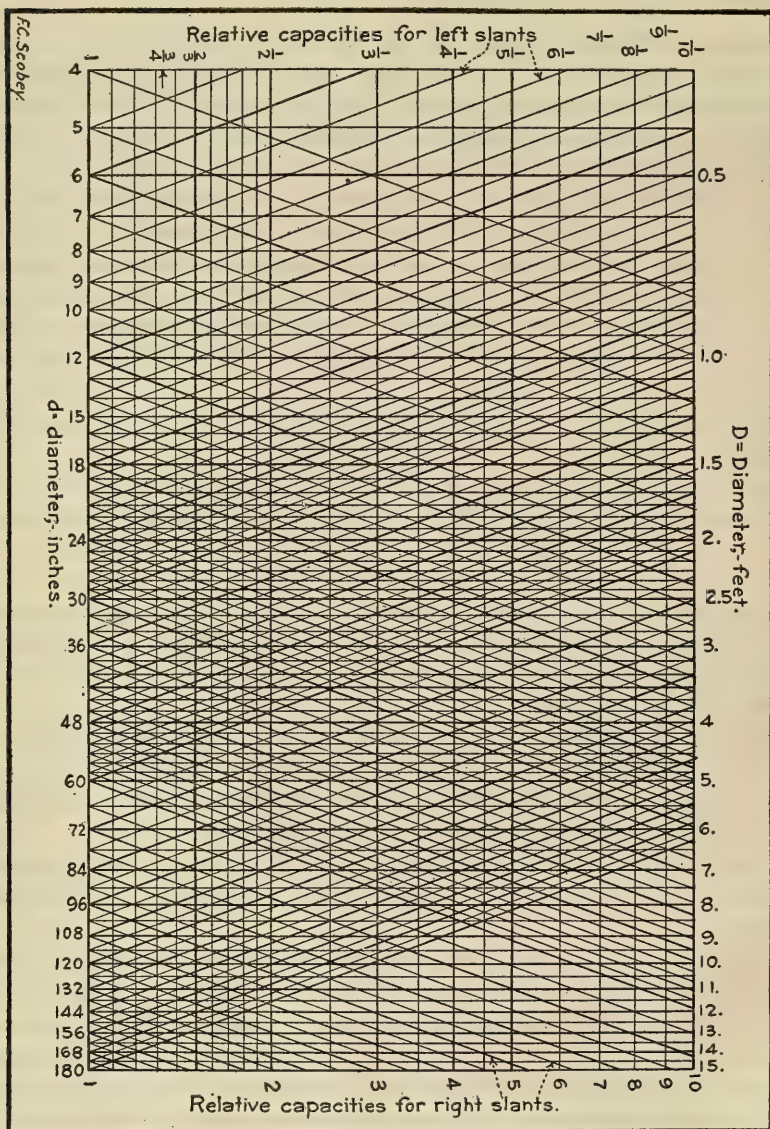


FIG. 6.—Logarithmic diagram showing relative capacities of wood-stave pipe of various diameters for any given hydraulic gradient. For instance, an 8-inch pipe will carry one-third as much as a 12-inch pipe, and an 18-inch pipe will carry three times as much as a 12-inch pipe. For the first problem, enter the diagram at the bottom (as noted) on the left slanting line leading from 12 inches as a base. The intersection of this slant with the vertical line above 8 is approximately on the horizontal line representing $1/3$, as shown by figures at left of diagram. Similarly for the second problem follow the right slant from 12 as a base to the intersection of this slant with the vertical line from 18. This intersection is approximately on the horizontal line representing 3 as shown by figures at right of diagram.

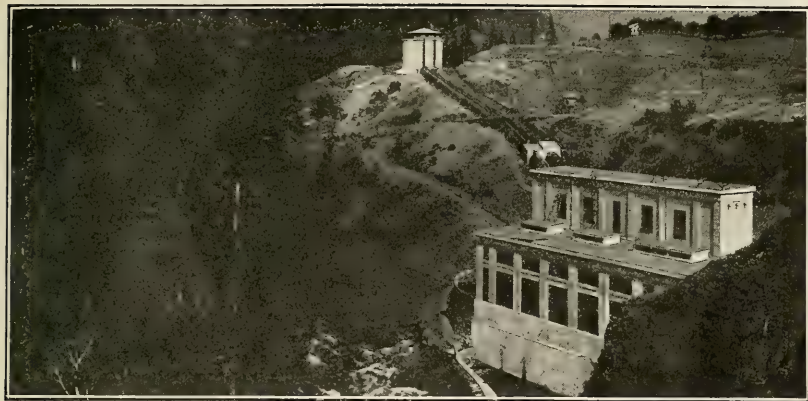


FIG. 1.—PIPES FROM SURGE TANK TO POWER HOUSE.
Right-hand pipe held at constant velocity. 13½-foot pipe in distance. (No. 52.)

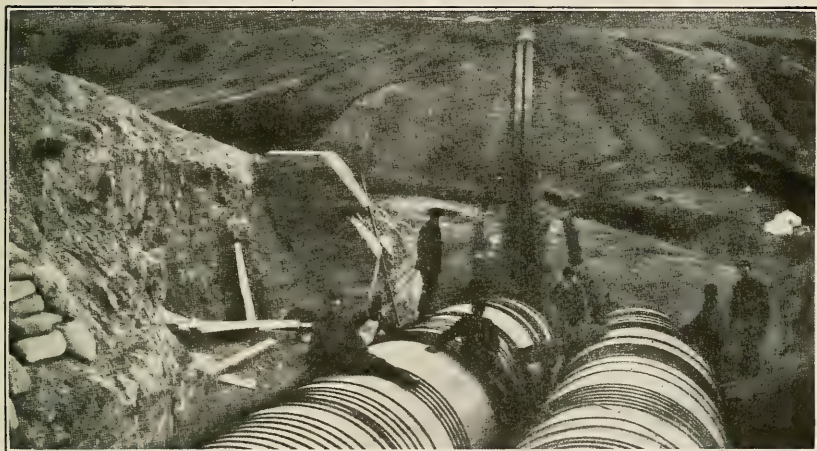


FIG. 2.—AN EXAMPLE OF TWIN LINE CONSTRUCTION.



FIG. 3.—WINTER FLOW IS RETARDED BY SLUSH ICE.
Note rings for grating removed to prevent ice accumulation.



FIG. 1.—TYPICAL OUTLET STRUCTURE. WILL PARTIALLY RECOVER VELOCITY HEAD.
Pipe is one-half diameter too high for inlet structure. Too much air would enter.

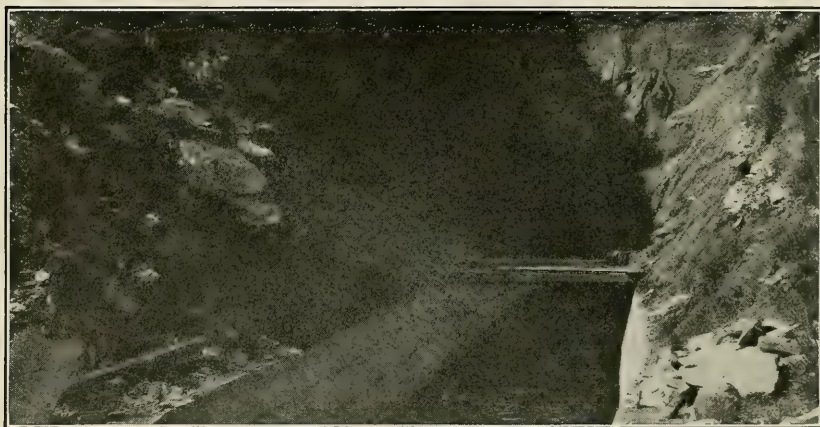


FIG. 2.—VIEW TAKEN FROM STRUCTURE IN FIGURE 3.
Hillside cut ravelings enter pipe and reduce capacity. A condition to be avoided.

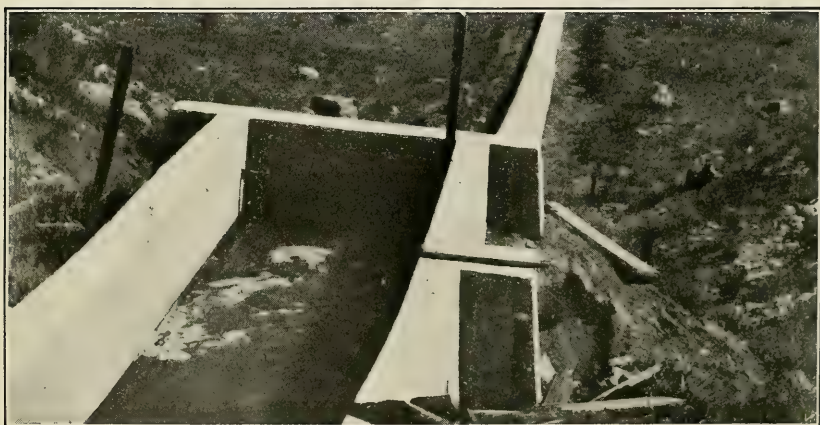


FIG. 3.—ENTRANCE WELL SUBMERGED, REDUCING AMOUNT OF AIR CARRIED INTO PIPE.



FIG. 1.—SIPHON UNDER UNION PACIFIC RAILROAD, ROCK CREEK CONSERVATION CO., WYOMING.

Form for inlet bowl to reduce entry loss. Pipe under construction in distance. See figures 2 and 3.

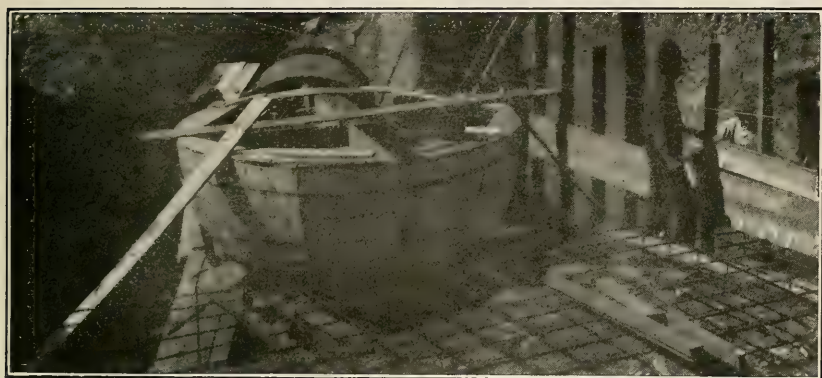


FIG. 2.—FORM FOR BOWL, FLOOR REINFORCEMENT, AND CAST-IRON PIPE FOR INLET SECTION FOR STRUCTURE IN FIGURES 1 AND 3.

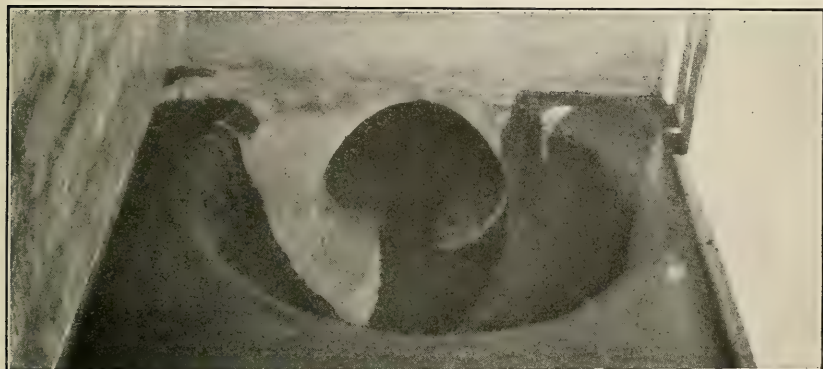


FIG. 3.—SIPHON INLET MADE FROM FORM SHOWN IN FIGURES 1 AND 2. ENTRANCE WELL SUBMERGED, PREVENTING AIR BEING CARRIED INTO PIPE.

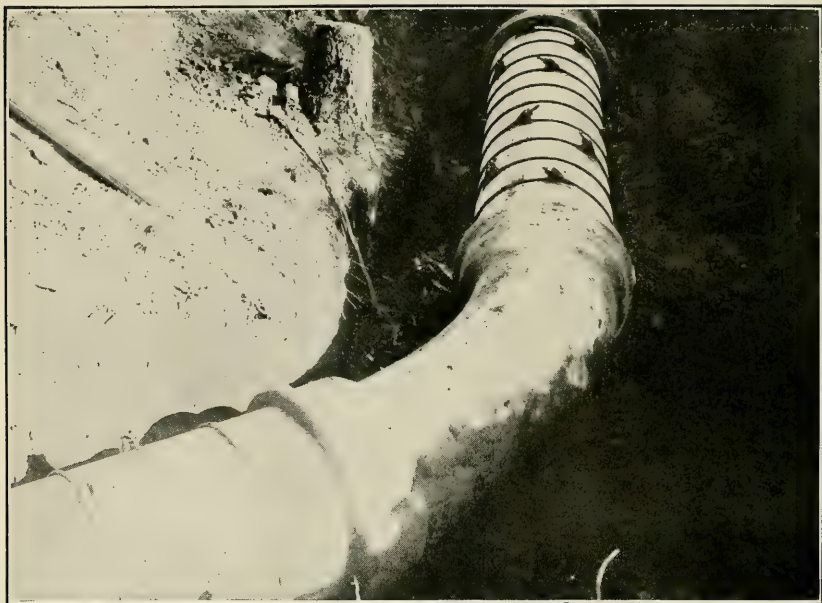


FIG. 1.—EVEN WITH 27 CAST-IRON BENDS LIKE THIS THE ASTORIA, WASH., PIPE SHOWS A CAPACITY 17 PER CENT MORE THAN THE AVERAGE. (No. 23.)

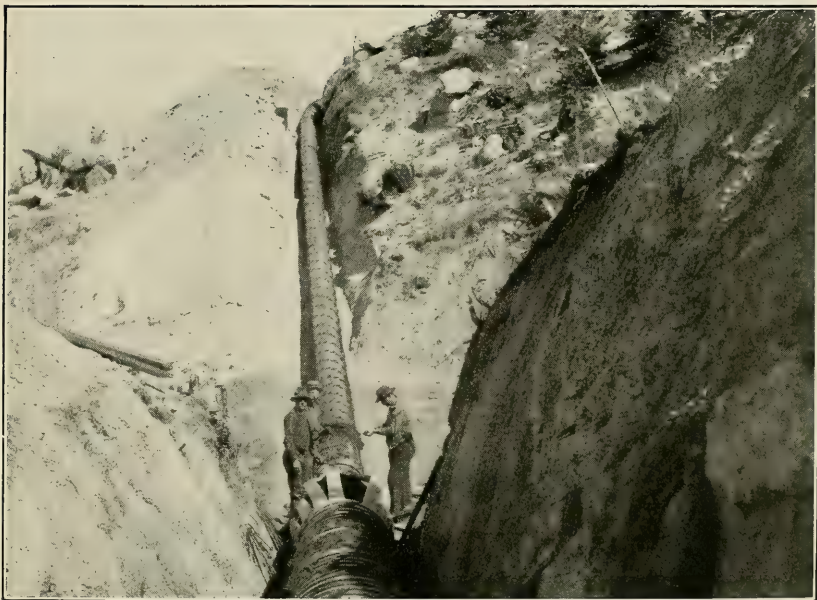


FIG. 2.—PIPE FOR BUTTE, MONT., MUNICIPAL SUPPLY. (No. 32.) SPRINGING IN A BUCKLE JOINT.

TABLE 7.—Velocity V in feet per second and loss of head H in feet per thousand feet of pipe, necessary to the conveyance of a given quantity of water, Q , in second-feet and in millions of U. S. gallons per day through wood-stave pipe, based on formula $H = \frac{7.68 V^{1.8}}{d^{1.17}}$. For instance, 5 second-feet will be carried by a 16-inch pipe at a velocity of 3.58 feet per second with a loss of head of 2.98 feet per thousand feet of pipe.

Quantity. Q	Inside diameter, in inches, and corresponding area, A, in square feet.														Quantity, millions per day.	
	4 A=0.0873.		5 A=0.1364.		6 A=0.1963.		7 A=0.2673.		8 A=0.3491.		9 A=0.4418.		10 A=0.5454.			
	V	H	V	H	V	H	V	H	V	H	V	H	V	H		
Sec.-ft.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Gals.	
0.2	2.29	6.7	1.47	2.33	1.02	0.98	0.75	0.4	0.57	0.25	.....	.....	.....	.....	0.129	
.4	4.58	23.4	2.93	8.10	2.04	3.40	1.50	1.63	1.15	.86	0.90	0.49	0.73	0.29	.259	
.6	6.87	48.7	4.40	16.8	3.06	7.05	2.24	3.38	1.72	1.79	1.36	1.02	1.10	1.60	.388	
.8	9.16	81.7	5.86	28.2	4.08	11.8	2.99	5.67	2.29	3.00	1.81	1.71	1.47	1.02	.517	
1.0	11.4	121	7.33	40.6	5.10	17.7	3.74	8.47	2.87	4.42	2.26	2.56	1.83	1.52	.646	
1.2	13.7	169	8.80	58.5	6.11	24.6	4.49	11.7	3.44	6.22	2.72	3.55	2.20	2.10	.776	
1.4	16.0	224	10.3	77.1	7.13	32.4	5.24	15.5	4.01	8.21	3.17	4.68	2.57	2.78	.905	
1.6	18.3	285	11.7	110	8.15	41.3	5.99	19.7	4.58	10.4	3.62	5.95	2.93	3.54	1.034	
1.8	20.6	352	13.2	121	9.17	51.0	6.73	24.4	5.16	12.9	4.07	7.35	3.30	4.37	1.163	
2.0	.....	.....	14.7	147	10.2	61.6	7.48	29.5	5.72	15.6	4.53	8.89	3.67	5.28	1.293	
2.5	.....	.....	18.3	219	12.7	92.1	9.35	44.1	7.16	23.3	5.66	13.6	4.58	7.89	1.616	
3.0	.....	.....	22.0	304	15.3	128	11.2	61.2	8.60	33.4	6.79	18.9	5.50	11.0	1.939	
3.5	.....	.....	.....	.....	17.8	169	13.1	80.6	10.0	42.7	7.02	25.2	6.42	14.5	2.262	
4.0	.....	.....	.....	.....	20.4	215	15.0	103	11.5	53.7	9.05	31.9	7.33	18.6	2.585	
4.5	.....	.....	.....	.....	.....	.....	16.8	127	12.9	67.1	10.2	39.4	8.25	22.7	2.908	
5.0	.....	.....	.....	.....	.....	.....	18.7	155	14.3	81.2	11.3	47.7	9.17	27.5	3.232	
5.5	.....	.....	.....	.....	.....	.....	20.6	182	15.8	96.4	12.4	56.6	10.1	32.6	3.555	
6.0	.....	.....	.....	.....	.....	.....	.....	.....	17.2	113	13.6	65.4	11.0	38.2	3.878	
6.5	.....	.....	.....	.....	.....	.....	.....	.....	18.6	130	14.7	76.5	11.9	44.1	4.201	
7.0	.....	.....	.....	.....	.....	.....	.....	.....	20.1	149	15.8	87.3	12.8	50.3	4.524	
		12 A=0.7854.		14 A=1.069.		16 A=1.396.		18 A=1.767.		20 A=2.182.		22 A=2.640.		24 A=3.142.		
		V	H	V	H	V	H	V	H	V	H	V	H	V	H	
1.0	1.27	0.65	0.94	0.31	0.72	0.16	0.57	0.09								0.646
1.2	1.53	.90	1.12	.43	.86	.23	.68	.13	0.55	0.08						.776
1.4	1.78	1.19	1.31	.57	1.00	.30	.79	.17	.64	.10	0.53	0.07				.905
1.6	2.04	1.51	1.50	.72	1.15	.38	.91	.22	.73	.13	.61	.08				1.034
1.8	2.29	1.87	1.68	.90	1.29	.47	1.02	.27	.83	.16	.68	.10				1.163
2.0	2.55	2.26	1.87	1.08	1.43	.57	1.13	.33	.92	.20	.76	.12	0.64	0.08	1.293	
2.5	3.18	3.37	2.34	1.62	1.79	.85	1.42	.49	1.15	.29	.95	.19	.80	.12	1.616	
3.0	3.82	4.67	2.81	2.24	2.15	1.19	1.70	.68	1.37	.41	1.14	.26	.95	.17	1.939	
3.5	4.46	6.17	3.27	2.96	2.51	1.57	1.98	.89	1.60	.54	1.33	.34	1.11	.23	2.262	
4.0	5.09	7.86	3.74	3.76	2.87	1.99	2.23	1.14	1.83	.69	1.52	.44	1.27	.29	2.585	
4.5	5.73	9.69	4.21	4.65	3.22	2.46	2.55	1.40	2.06	.85	1.70	.54	1.43	.36	2.908	
5.0	6.37	11.7	4.68	5.63	3.58	2.98	2.83	1.70	2.29	1.03	1.89	.65	1.59	.43	3.232	
5.5	7.00	13.9	5.15	6.67	3.94	3.49	3.11	2.02	2.52	1.22	2.08	.78	1.75	.51	3.555	
6.0	7.64	16.3	5.61	7.80	4.30	4.13	3.40	2.32	2.75	1.42	2.27	.90	1.91	.60	3.878	
6.5	8.27	18.8	6.08	9.02	4.66	4.77	3.68	2.72	2.98	1.65	2.46	1.04	2.07	.69	4.201	
7.0	8.91	21.5	6.55	10.3	5.01	5.45	3.96	3.11	3.21	1.88	2.65	1.19	2.23	.79	4.524	
7.5	9.55	24.4	7.02	11.7	5.37	6.16	4.24	3.52	3.44	2.13	2.84	1.35	2.39	.89	4.847	
8.0	10.2	27.3	7.48	13.1	5.73	6.94	4.53	3.96	3.67	2.39	3.03	1.52	2.55	1.00	5.171	
8.5	10.8	30.5	7.95	14.6	6.09	7.73	4.81	4.41	3.90	2.67	3.22	1.69	2.71	1.12	5.494	
9.0	11.5	33.7	8.42	16.4	6.45	8.40	5.10	4.89	4.12	2.96	3.41	1.87	2.86	1.24	5.817	
9.5	12.1	37.2	8.89	17.9	6.80	9.45	5.38	5.39	4.35	3.27	3.60	2.06	3.02	1.37	6.140	
10	12.7	40.8	9.35	19.6	7.16	10.4	5.66	5.91	4.58	3.59	3.79	2.27	3.18	1.49	6.463	
11	14.0	48.5	10.3	23.2	7.88	12.3	6.22	7.01	5.04	4.28	4.17	2.68	3.50	1.78	7.109	
12	15.3	56.8	11.2	27.3	8.60	14.4	6.79	8.21	5.50	4.97	4.55	3.16	3.82	2.08	7.756	
13	16.6	65.6	12.2	31.4	9.31	16.6	7.36	9.48	5.96	5.74	5.92	3.63	4.14	2.41	8.402	
14	17.8	74.8	13.1	35.9	10.0	19.0	7.92	10.8	6.42	6.55	5.30	4.15	4.46	2.74	9.048	
15	19.1	84.7	14.0	40.8	10.7	21.5	8.49	12.3	6.87	7.43	6.00	4.70	4.77	3.11	9.695	
16	20.4	95.2	15.0	45.7	11.5	24.2	9.06	13.8	7.33	8.33	6.06	5.28	5.09	3.49	10.341	
17	.....	.....	15.9	51.0	12.2	27.0	9.62	15.4	7.79	9.30	6.44	5.74	5.41	3.90	10.987	
18	.....	.....	16.8	56.6	12.9	29.8	10.2	17.0	8.25	10.3	6.82	6.54	5.73	4.31	11.634	
19	.....	.....	17.8	62.2	13.6	32.9	10.7	18.8	8.71	11.4	7.20	7.20	6.05	4.76	12.280	
20	.....	.....	18.7	68.1	14.3	36.1	11.3	20.6	9.17	12.4	7.58	7.90	6.37	5.22	12.926	
21	.....	.....	19.6	74.5	15.0	39.4	11.9	22.5	9.62	13.6	7.96	8.63	6.68	5.70	13.573	
22	.....	.....	20.6	81.1	15.8	42.9	12.4	24.4	10.1	14.8	8.33	9.37	7.00	6.19	14.219	
23	.....	.....	.....	.....	16.5	46.4	13.0	26.5	10.5	16.0	8.71	10.2	7.32	6.71	14.865	
24	.....	.....	.....	.....	17.2	50.1	13.6	28.5	11.0	17.3	9.09	11.0	7.64	7.25	15.512	
25	.....	.....	.....	.....	17.9	54.0	14.1	30.9	11.5	18.6	9.47	11.8	7.96	7.79	16.158	
26	.....	.....	.....	.....	18.6	57.9	14.7	33.0	11.9	19.9	9.85	12.7	8.27	8.37	16.804	
27	.....	.....	.....	.....	19.3	61.9	15.3	35.3	12.4	21.3	10.2	13.6	8.59	8.95	17.451	
28	.....	.....	.....	.....	20.1	66.1	15.8	37.7	12.8	22.8	10.6	14.5	8.91	9.56	18.097	

TABLE 7 (Continued).—Velocity V in feet per second and loss of head H in feet per thousand feet of pipe, necessary to the conveyance of a given quantity of water, Q , in second-feet and in millions of U. S. gallons per day through wood-stave pipe. For instance, 160 second-feet will be carried by a 42-inch pipe at a velocity of 16.6 feet per second with a loss of head of 15.3 feet per thousand feet of pipe.

Quantity.	Inside diameter, in inches and corresponding area, A, in square feet.														Quantity, millions per day.
	26 A=3.687.		28 A=4.276.		30 A=4.909.		32 A=5.585.		34 A=6.305.		36 A=7.069.		38 A=7.876.		
	V	H	V	H	V	H	V	H	V	H	V	H	V	H	
Sec.-ft.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Gals.
8	2.17	0.68	1.87	0.48	1.63	0.34	1.43	0.25	1.27	0.19	1.13	0.14	1.02	0.11	5.171
9	2.44	.85	2.10	.59	1.83	.43	1.61	.31	1.43	.23	1.27	.18	1.14	.14	5.817
10	2.71	1.02	2.34	.72	2.04	.52	1.79	.38	1.59	.28	1.41	.22	1.27	.17	6.463
11	2.98	1.21	2.57	.85	2.24	.62	1.97	.45	1.75	.34	1.56	.26	1.40	.20	7.109
12	3.25	1.42	2.81	1.00	2.45	.72	2.15	.53	1.90	.39	1.70	.30	1.52	.23	7.756
13	3.53	1.64	3.04	1.15	2.65	.82	2.33	.61	2.06	.46	1.84	.35	1.65	.27	8.402
14	3.80	1.87	3.27	1.32	2.85	.95	2.51	.70	2.22	.52	1.98	.40	1.78	.31	9.048
16	4.34	2.38	3.74	1.67	3.26	1.20	2.87	.89	2.54	.67	2.26	.50	2.03	.39	10.341
18	4.88	2.94	4.21	2.07	3.67	1.49	3.22	1.09	2.86	.82	2.55	.62	2.29	.48	11.634
20	5.42	3.56	4.68	2.50	4.07	1.80	3.58	1.32	3.17	.99	2.83	.75	2.54	.58	12.926
22	5.97	4.23	5.15	2.96	4.48	2.14	3.94	1.57	3.49	1.18	3.11	.90	2.79	.69	14.219
24	6.51	4.94	5.61	3.47	4.89	2.50	4.30	1.84	3.81	1.38	3.40	1.05	3.05	.81	15.512
26	7.05	5.70	6.08	4.02	5.30	2.89	4.66	2.12	4.12	1.59	3.68	1.21	3.30	.93	16.804
28	7.59	6.55	6.55	4.58	5.70	3.30	5.01	2.42	4.44	1.82	3.96	1.38	3.56	1.07	18.097
30	8.14	7.40	7.02	5.18	6.11	3.73	5.37	2.74	4.76	2.05	4.24	1.56	3.81	1.21	19.389
32	8.68	8.30	7.48	5.82	6.52	4.19	5.73	3.08	5.08	2.29	4.53	1.76	4.06	1.36	20.682
36	9.76	10.25	8.42	7.19	7.33	5.18	6.45	3.81	5.71	2.85	5.09	2.17	4.57	1.67	23.267
40	10.8	12.4	9.35	8.72	8.15	6.26	7.16	4.61	6.34	3.45	5.66	2.62	5.08	2.04	25.853
45	12.2	15.3	10.5	10.8	9.17	7.74	8.06	5.70	7.14	4.27	6.37	3.25	5.71	2.51	29.084
50	13.6	18.5	11.7	13.0	10.2	9.36	8.95	6.90	7.93	5.16	7.07	3.92	6.35	3.04	32.316
55	14.9	22.0	12.9	15.5	11.2	11.1	9.85	8.15	8.72	6.11	7.78	4.66	6.98	3.59	35.547
60	16.3	25.6	14.0	18.1	12.2	13.0	10.7	9.56	9.52	7.16	8.49	5.44	7.62	4.21	38.779
65	17.6	29.6	15.2	20.9	13.2	15.0	11.6	11.0	10.3	8.27	9.20	6.29	8.25	4.87	42.010
70	19.0	33.9	16.4	23.8	14.3	17.1	12.5	12.6	11.1	9.44	9.90	7.19	8.89	5.55	45.242
75	20.3	38.2	17.5	26.9	15.3	19.4	13.4	14.3	11.9	10.7	10.6	8.13	9.52	6.29	48.474
80	.....	.....	18.7	30.2	16.3	21.8	14.3	16.0	12.7	12.0	11.4	9.13	10.2	7.07	51.705
85	.....	.....	19.9	33.9	17.3	24.3	15.2	17.9	13.5	13.4	12.0	10.2	10.8	7.87	54.937
90	.....	.....	21.0	37.4	18.3	28.4	16.1	19.8	14.3	14.8	12.7	11.3	11.4	8.73	58.168
95	.....	.....	.....	.....	19.4	29.7	17.0	21.8	15.1	16.4	13.4	12.5	12.1	9.61	61.400
100	.....	.....	.....	.....	20.4	32.6	17.9	24.0	15.9	17.9	14.2	13.7	12.7	10.6	64.632
		40 A=8.727		42 A=9.621.		44 A=10.56.		46 A=11.54.		48 A=12.57.		54 A=15.90.		60 A=19.64.	
		V	H	V	H	V	H	V	H	V	H	V	H	V	H
30	3.44	0.95	3.12	0.75	2.85	0.60	2.60	0.49	2.39	0.40	1.89	0.23	1.53	0.14	19.389
35	4.01	1.26	3.64	.99	3.31	.79	3.03	.64	2.78	.52	2.20	.30	1.78	.18	22.621
40	4.58	1.59	4.16	1.26	3.79	1.00	3.47	.82	3.18	.67	2.52	.38	2.04	.23	25.853
45	5.16	1.97	4.68	1.56	4.26	1.25	3.90	1.01	3.58	.82	2.83	.47	2.29	.28	29.084
50	5.57	2.26	5.20	1.88	4.74	1.50	4.33	1.22	3.98	.99	3.14	.57	2.55	.34	32.316
55	6.30	2.82	5.72	2.24	5.21	1.79	4.77	1.45	4.38	1.18	3.46	.67	2.80	.41	35.547
60	6.88	3.29	6.24	2.62	5.68	2.09	5.20	1.69	4.77	1.38	3.77	.79	3.06	.48	38.779
65	7.45	3.8	6.76	3.01	6.16	2.42	5.63	1.95	5.17	1.59	4.09	.91	3.31	.55	42.010
70	8.02	4.36	7.28	3.44	6.63	2.76	6.07	2.23	5.57	1.82	4.40	1.04	3.56	.63	45.242
75	8.59	4.92	7.8	3.89	7.10	3.12	6.50	2.53	5.97	2.06	4.72	1.18	3.82	.73	48.474
80	9.17	5.53	8.32	4.37	7.58	3.51	6.93	2.84	6.36	2.31	5.03	1.32	4.07	.80	51.705
85	9.74	6.16	8.84	4.88	8.05	3.92	7.37	3.17	6.76	2.58	5.35	1.47	4.33	.89	54.937
90	10.3	6.84	9.36	5.41	8.52	4.34	7.8	3.53	7.16	2.87	5.66	1.63	4.58	.99	58.168
95	10.9	7.55	9.87	5.96	9.00	4.78	8.23	3.87	7.56	3.16	5.98	1.80	4.84	1.09	61.400
100	11.5	8.30	10.4	6.55	9.47	5.24	8.67	4.25	7.96	3.46	6.29	1.97	5.09	1.19	64.631
110	12.6	9.79	11.4	7.77	10.4	6.24	9.53	5.04	8.75	4.11	6.92	2.35	5.6	1.42	71.095
120	13.8	11.5	12.5	9.09	11.4	7.23	10.4	5.89	9.55	4.81	7.55	2.74	6.11	1.65	77.558
130	14.9	13.3	13.5	10.5	12.3	8.41	11.3	6.81	10.34	5.55	8.18	3.17	6.62	1.91	84.021
140	16.0	15.1	14.6	12.0	13.3	9.60	12.1	8.64	11.1	6.35	8.81	3.62	7.13	2.19	90.484
150	17.2	17.1	15.6	13.6	14.2	10.9	13.0	8.81	11.9	7.18	9.43	4.10	7.64	2.48	96.947
160	18.3	19.3	16.6	15.3	15.2	12.2	13.9	9.89	12.7	8.07	10.1	4.60	8.15	2.78	103.41
170	19.5	21.4	17.7	17.0	16.1	13.6	14.7	11.0	13.5	8.98	10.7	5.13	8.66	3.12	109.87
180	20.6	23.8	18.7	18.9	17.0	15.1	15.6	12.2	14.3	9.96	11.3	5.70	9.17	3.43	116.34
190	.....	.....	19.8	20.8	18.0	16.7	16.5	13.5	15.1	11.0	12.0	6.28	9.67	3.79	122.80
200	.....	.....	20.8	22.8	18.9	18.3	17.3	14.8	15.9	12.1	12.6	6.89	10.2	4.16	129.26
210	.....	.....	.....	.....	19.8	20.0	18.2	16.1	16.7	13.2	13.2	7.51	10.7	4.54	135.73
220	.....	.....	.....	.....	20.8	21.7	19.1	17.5	17.5	14.3	13.8	8.17	11.2	4.94	142.19
230	.....	.....	.....	.....	.....	.....	19.9	19.0	18.3	15.5	14.5	8.86	11.7	5.34	148.65
240	.....	.....	.....	.....	.....	.....	20.8	20.5	19.1	16.8	15.1	9.54	12.2	5.78	155.12
250	.....	.....	.....	.....	.....	.....	.....	.....	19.9	18.0	15.7	10.3	12.7	6.22	161.58

TABLE 7 (Continued).—Velocity V in feet per second and less of head H in feet per thousand feet of pipe, necessary to the conveyance of a given quantity of water, Q , in second-feet and in millions of U. S. gallons per day through wood-stave pipe. For instance, 550 second-feet will be carried by a 120-inch pipe at a velocity of 7 feet per second with a loss of head of 0.94 foot per thousand feet of pipe.

Quantity.	Inside diameter, in inches and corresponding area, A, in square feet.														Quantity, mil- lions per day.
	66 A=23.76		72 A=28.27		78 A=33.18		84 A=38.48		90 A=44.18		96 A=50.26		102 A=56.74		
Q	V	H	V	H	V	H	V	H	V	H	V	H	V	H	
Sec.-ft.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Gals.
60	2.53	0.30	2.12	0.20	1.81	0.14	1.56	0.10	1.36	0.07	1.19	0.05	1.05	0.04	38.78
70	2.95	.40	2.48	.26	2.11	.18	1.82	.13	1.58	.09	1.39	.07	1.23	.05	45.24
80	3.37	.51	2.83	.33	2.41	.23	2.08	.16	1.81	.12	1.59	.09	1.41	.06	51.70
90	3.79	.63	3.18	.41	2.71	.28	2.34	.20	2.04	.14	1.79	.11	1.59	.08	58.17
100	4.21	.76	3.54	.50	3.01	.34	2.60	.24	2.26	.17	1.99	.13	1.76	.09	64.63
110	4.63	.90	3.89	.59	3.32	.41	2.86	.28	2.49	.20	2.19	.15	1.94	.11	71.09
120	5.05	1.05	4.25	.69	3.62	.47	3.12	.33	2.72	.24	2.39	.18	2.11	.13	77.56
130	5.47	1.21	4.60	.80	3.92	.55	3.38	.38	2.94	.28	2.59	.20	2.29	.15	84.02
140	5.89	1.39	4.95	.91	4.22	.63	3.64	.44	3.17	.32	2.79	.23	2.47	.17	90.48
150	6.31	1.57	5.31	1.04	4.52	.71	3.90	.50	3.39	.36	2.98	.26	2.64	.20	96.95
160	6.73	1.77	5.66	1.17	4.82	.80	4.16	.56	3.62	.40	3.18	.30	2.82	.22	103.41
170	7.16	1.97	6.01	1.30	5.12	.89	4.42	.62	3.85	.45	3.38	.33	3.00	.25	109.87
180	7.58	2.18	6.37	1.44	5.43	.99	4.68	.69	4.07	.50	3.58	.37	3.17	.27	116.34
190	8.00	2.41	6.72	1.59	5.73	1.08	4.94	.76	4.30	.55	3.78	.40	3.35	.30	122.80
200	8.42	2.64	7.08	1.74	6.03	1.19	5.20	.84	4.53	.60	3.98	.44	3.53	.33	129.26
220	9.26	3.14	7.78	2.06	6.63	1.41	5.72	.99	4.98	.71	4.38	.53	3.88	.39	142.19
240	10.1	3.67	8.49	2.42	7.23	1.65	6.24	1.16	5.43	.83	4.78	.62	4.23	.46	155.12
260	10.9	4.23	9.20	2.79	7.84	1.91	6.76	1.34	5.88	.95	5.17	.71	4.58	.53	168.04
280	11.8	4.86	9.90	3.20	8.44	2.18	7.28	1.53	6.34	1.11	5.57	.81	4.94	.61	180.97
300	12.6	5.48	10.6	3.61	9.04	2.47	7.80	1.74	6.79	1.25	5.96	.92	5.29	.69	193.89
320	13.5	6.17	11.3	4.06	9.64	2.78	8.32	1.95	7.24	1.40	6.37	1.03	5.64	.77	206.82
340	14.3	6.86	12.0	4.53	10.3	3.09	8.84	2.17	7.70	1.56	6.77	1.15	5.99	.86	219.75
360	15.2	7.60	12.7	5.01	10.9	3.43	9.36	2.41	8.15	1.74	7.16	1.27	6.35	.95	232.67
380	16.0	8.39	13.4	5.53	11.5	3.78	9.88	2.66	8.60	1.91	7.56	1.40	6.70	1.05	245.60
400	16.8	9.19	14.2	6.05	12.1	4.14	10.4	2.91	9.05	2.10	7.96	1.54	7.05	1.15	258.53
450	18.9	11.4	15.9	7.52	13.6	5.12	11.7	3.60	10.2	2.59	8.95	1.91	7.93	1.42	290.84
500	21.0	13.7	17.7	9.06	15.1	6.20	13.0	4.35	11.3	3.13	9.95	2.32	8.81	1.72	323.16
550	-----	-----	19.5	10.8	16.6	7.37	14.3	5.17	12.5	3.71	10.9	2.74	9.69	2.04	355.47
600	-----	-----	21.2	12.6	18.1	8.59	15.6	6.03	13.6	4.33	11.9	3.20	10.6	2.39	387.79
650	-----	-----	-----	-----	19.6	9.90	16.9	6.98	14.7	5.02	12.9	3.76	11.5	2.76	420.10
108 A=63.62		114 A=70.88		120 A=78.54		132 A=95.03		144 A=113.1		156 A=132.7		168 A=153.94			
V	H	V	H	V	H	V	H	V	H	V	H	V	H	V	H
200	3.14	0.25	2.82	0.19	2.55	0.15	2.10	0.10	1.77	0.06	1.51	0.04	1.30	0.03	129.26
250	3.93	.38	3.53	.24	3.18	.23	2.63	.14	2.21	.10	1.88	.07	1.62	.05	161.58
300	4.72	.52	4.23	.40	3.82	.32	3.16	.20	2.65	.13	2.26	.09	1.95	.06	193.89
350	5.50	.68	4.94	.53	4.46	.42	3.68	.26	3.09	.17	2.64	.12	2.27	.08	226.21
400	6.29	.88	5.64	.67	5.09	.53	4.21	.34	3.54	.22	3.01	.15	2.60	.11	258.53
450	7.07	1.09	6.35	.83	5.73	.66	4.74	.42	3.98	.27	3.39	.19	2.92	.13	290.84
500	7.86	1.31	7.05	1.01	6.37	.79	5.26	.50	4.42	.33	3.77	.23	3.25	.16	323.16
550	8.65	1.56	7.76	1.21	7.00	.94	5.79	.60	4.86	.39	4.15	.27	3.57	.19	355.47
600	9.43	1.82	8.46	1.42	7.64	1.10	6.31	.70	5.31	.46	4.52	.31	3.90	.22	387.79
650	10.2	2.11	9.17	1.63	8.28	1.27	6.84	.81	5.75	.53	4.90	.36	4.22	.26	420.10
700	11.0	2.40	9.88	1.86	8.91	1.45	7.37	.92	6.19	.61	5.28	.42	4.55	.29	452.42
750	11.8	2.72	10.6	2.11	9.55	1.65	7.89	1.04	6.63	.69	5.65	.47	4.87	.33	484.74
800	12.6	3.04	11.3	2.37	10.2	1.85	8.42	1.17	7.07	.77	6.03	.53	5.20	.37	517.05
850	13.4	3.41	12.0	2.65	10.8	2.06	8.94	1.31	7.52	.86	6.41	.59	5.52	.41	549.37
900	14.2	3.79	12.7	2.94	11.5	2.29	9.47	1.45	7.96	.96	6.78	.65	5.85	.45	581.68
950	14.9	4.17	13.4	3.23	12.1	2.52	10.0	1.60	8.40	1.06	7.16	.73	6.17	.51	614.00
1,000	15.7	4.57	14.1	3.54	12.7	2.76	10.5	1.75	8.84	1.15	7.54	.79	6.50	.56	646.31
1,050	16.5	5.00	14.8	3.86	13.4	3.02	11.1	1.91	9.28	1.26	7.91	.86	6.82	.61	678.63
1,100	17.3	5.42	15.5	4.20	14.0	3.28	11.6	2.08	9.73	1.37	8.29	.94	7.15	.66	710.95
1,150	18.1	5.88	16.2	4.55	14.6	3.55	12.1	2.25	10.2	1.49	8.67	1.00	7.47	.71	743.26
1,200	18.9	6.34	16.9	4.90	15.4	3.84	12.6	2.43	10.6	1.61	9.04	1.10	7.80	.77	775.58
1,250	19.7	6.83	17.6	5.30	15.9	4.13	13.1	2.62	11.1	1.73	9.42	1.18	8.12	.83	807.90
1,300	20.4	7.32	18.3	5.70	16.6	4.43	13.7	2.81	11.5	1.86	9.80	1.27	8.45	.89	840.21
1,400	-----	-----	19.8	6.50	17.8	5.06	14.7	3.21	12.4	2.12	10.6	1.45	9.09	1.02	904.84
1,500	-----	-----	21.2	7.34	19.1	5.73	15.8	3.66	13.3	2.31	11.3	1.64	9.74	1.15	969.47
1,600	-----	-----	-----	-----	20.4	6.44	16.8	4.09	14.2	2.70	12.1	1.84	10.4	1.29	1,034.1
1,700	-----	-----	-----	-----	-----	-----	17.9	4.56	15.0	3.01	12.8	2.05	11.0	1.44	1,088.7
1,800	-----	-----	-----	-----	-----	-----	18.9	5.05	15.9	3.34	13.6	2.28	11.7	1.58	1,163.4
1,900	-----	-----	-----	-----	-----	-----	20.0	5.57	16.8	3.68	14.3	2.51	12.3	1.76	1,228.0
2,000	-----	-----	-----	-----	-----	-----	21.1	6.11	17.7	4.02	15.1	2.75	13.0	1.93	1,292.6

CAPACITY OF WOOD-STAVE PIPE COMPARED WITH THAT OF CAST-IRON AND RIVETED STEEL.

Table 8 gives the relative carrying capacities of wood, steel, and cast-iron pipes. The table is based on velocities of about 1, 3, and 7 feet per second in the steel and cast-iron pipes of diameters ranging from 4 to 144 inches. For a given velocity the loss of head for new cast-iron, new riveted steel, 10-year-old cast-iron, 20-year-old cast-iron, and 10-year-old-riveted steel is based on values of C_w in the Williams-Hazen formula (No. 8, p. 6) of 130, 110, 110, 100 and 100, respectively, these conservative values being recommended by Williams and Hazen. (See Mr. Williams's discussion, p. 82.)

TABLE 8.—Relative capacity, in per cent, of wood-stave pipe, compared with new cast iron, new riveted, 10-year-old cast iron, 20-year-old cast iron, and 10-year-old riveted steel or iron pipe; based on Williams and Hazen recommendation for values of C , in their formula, of 130 for new cast iron, 110 for new riveted and 10-year-old cast iron, and 100 for 20-year-old cast iron and 10-year-old riveted steel or iron pipe.

Diam-eter.	Cast-iron and riveted pipes.				Wood-stave pipes.			Per cent of velocity in wood pipe over that in metal pipe (column 2), corresponding to columns 6, 7, 8, respectively.		
	Velocity per second.	Loss of head for velocity. (H)			Velocities corresponding to losses in columns 3, 4, 5, respectively.					
		C _w =130.	C _w =110.	C _w =100.						
<i>Inches.</i>	<i>Feet.</i>	<i>Feet.</i>	<i>Feet.</i>	<i>Feet.</i>	<i>Feet.</i>	<i>Feet.</i>	<i>Feet.</i>			
4	1.02	1.380	-----	2.230	0.94	-----	1.24	-7.8	-----	+22
4	3.06	10.500	-----	17.100	2.90	-----	3.90	-5.2	-----	+26
4	6.64	44.000	-----	72.000	6.50	-----	8.70	-2.1	-----	+31
12	.99	.360	0.480	.580	.92	1.08	1.25	-7.1	+9.1	+21
12	2.96	2.730	3.710	4.430	2.83	3.33	3.70	-4.4	+12.0	+25
12	6.89	13.200	17.900	21.300	6.80	8.00	8.80	-1.3	+16.0	+28
36	1.09	.121	.164	.196	1.02	1.25	1.34	-6.4	+15.0	+23
36	3.06	.810	1.110	1.320	2.90	3.50	3.80	-5.2	+14.0	+24
36	7.00	3.740	5.100	6.100	6.90	8.10	9.00	-1.4	+16.0	+29
72	.98	.044	.060	.072	.92	1.10	1.20	-6.4	+12.0	+22
72	3.01	.349	.476	.570	2.90	3.50	3.80	-3.6	+16.0	+24
72	7.11	1.720	2.340	2.790	7.00	8.30	9.10	-1.4	+17.0	+28
108	1.10	.034	.046	.055	1.00	1.20	1.35	-8.0	+11.0	+23
108	3.14	.237	.321	.382	3.00	3.60	4.00	-4.5	+15.0	+27
108	6.92	1.020	1.380	1.650	6.90	8.00	9.00	-.3	+16.0	+30
144	1.06	.023	.031	.037	1.00	1.20	1.35	-5.7	+13.0	+21
144	3.01	.156	.211	.252	2.90	3.40	3.80	-3.7	+13.0	+26
144	7.07	.760	1.030	1.230	7.00	8.30	9.10	-1.0	+17.0	+29

For the same sized pipe and the various losses of head the corresponding velocities in wood-stave pipe (as shown by the new formula) are compared with the velocities in the metal pipes. This comparison is on a percentage basis, with the velocity of the metal pipe as the base. As an example: The loss of head in a new cast-iron pipe ($C_w=130$), 12 inches in diameter, for a velocity of 2.96 feet per second, is 2.73 feet per 1,000 feet of pipe. For the same velocity in new riveted steel or 10-year-old cast iron ($C_w=110$) the loss of head in a 12-inch pipe is 3.71 feet. For the same velocity in 10-year-old riveted steel or 20-year-old cast iron ($C_w=100$) the loss of head is 4.43 feet.

The velocity in a 12-inch wood-stave pipe for a loss of head of 2.73 feet per 1,000 feet of pipe is 2.83 feet per second or 4.4 per cent less than that in a new cast-iron pipe for the same loss of head.

The velocity in a 12-inch wood-stave pipe for a loss of head of 3.71 feet per 1,000 feet is 3.33 feet per second or 12.5 per cent more than that in a new riveted steel or 10-year-old cast-iron pipe for the same loss of head.

The velocity in a 12-inch wood-stave pipe for a loss of head of 4.43 feet per 1,000 feet is 3.7 feet per second, or 25 per cent more than that in a 10-year-old riveted steel or 20-year-old cast-iron pipe, for the same loss of head.

As shown by the table, the relative capacities change for various sizes of pipe and various velocities, but, speaking broadly, it is also shown that the capacity of wood-stave pipe is about 5 per cent less than that of new cast iron, 15 per cent more than that of new riveted steel or 10-year-old cast iron, and 25 per cent more than that of 10-year-old riveted steel or 20-year-old cast-iron pipe.

CONCLUSIONS.

A study of the previous pages appears to warrant the following general conclusions concerning the capacity of wood-stave pipes:

1. That the new formula herein offered is the best now available for use in the design of wood-stave pipes, as its application meets (within 1 per cent) the mean of all observations and the mean capacity of all wood pipes upon which experiments have been made.

2. That a very conservative factor of safety should be used where a guaranteed capacity is to be attained.

3. That the Kutter modification of the Chezy formula is not well adapted to the design of wood-stave pipes.

4. That the data now existing do not show that the capacity of wood-stave pipe either increases or decreases with age. This statement, of course, does not consider sedimentation, a purely mechanical process.

5. That if silted waters are to be conveyed the pipe should be designed for a working velocity of from 5 to 10 feet per second.

6. That if sand is present in the water, the design should be for a velocity of about 5 feet per second, which will be high enough to carry out a large part of the sand and at the same time not so high as to seriously erode the pipe. The better method, of course, is to remove the sand by sumps or other means.

7. That air should be removed from the intake end of every pipe line, especially when the capacity load is approached.

8. That wood pipe will convey about 15 per cent more water than a 10-year-old cast-iron pipe or a new riveted pipe, and about 25 per cent more than a cast-iron pipe 20 years old or a riveted pipe 10 years old.

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APPENDIX.

The following pages are devoted to abstracts of descriptions of experiments made by agencies other than the division of Irrigation Investigations, Office of Public Roads and Rural Engineering. The number before each description refers to the corresponding numbers in columns 1, Tables 2 and 3.

No. 1. Expt. HS-X, 1½-inch Jointed (Bored) Redwood Pipe,¹ New Almaden, Cal.—In 1877 Hamilton Smith, jr., made tests for loss of head in a straight pipe of eight joints, made of heart redwood, bored by a pipe auger. The pipes were new and uncoated. Connections were made by driving one joint into another, an outer iron band preventing splitting during this process. The area of the pipe was determined by weighing the water contained in each joint. The total loss of head was determined from the difference in elevation of the water surface over the inlet and at the mid-point of outlet (discharge being into open air). To ascertain friction head the velocity and entry heads were deducted from the effective head. The discharge was measured accurately in a rectangular wooden tank having a total capacity of 15.2 cubic feet. In this series of tests the pipe and water discharges were so small that laboratory accuracy was practicable. This series was used by Tutton but not by Williams-Hazen, Moritz, nor the writer in derivation of formulas. The line is not a stave pipe.

Nos. 2-3. 4-inch Jointed (Machine-Banded) Wood-Stave Pipe, Sunnyside Project, U. S. Reclamation Service, Washington.²—This pipe had been used for three years for irrigation purposes when tested by Moritz. It is straight in horizontal alignment, on a continuous down grade. Discharge was measured over a 12-inch Cipolletti weir. A fungous growth was noted at the inlet, being from one-eighth to three-sixteenths inch thick. The condition of the interior of the pipe was not known. The short reach (No. 2) was included in the longer reach (No. 3). The capacity of this pipe is 12 per cent less than the discharge computed by the new formula, probably due to the fungous growth. This conclusion is reached by taking the mean of observations on reaches 2 and 3 together.

No. 4. 5-inch Jointed (Machine-Banded) Wood-Stave Pipe, Sunnyside Project, U. S. Reclamation Service, Washington.—This line had been used for about two years at the time of the tests, for conveying irrigation water across a wide, shallow depression. Horizontal alignment was straight. Discharge was measured over an 8-inch sharp-crested Cipolletti weir. Water columns were used for gauge No. 1 for all runs except 3 and 4, and for gauge No. 2. For runs 3 and 4 a mercury manometer was used at gauge No. 1. Some trouble with air in the pipe was experienced in these tests. The capacity of the pipe was about 5 per cent less than the discharge computed by the new formula.

¹ Hydraulics. Hamilton Smith, jr., John Wiley & Sons, N. Y. (1886), p. 297.

² All tests made on the Sunnyside project were by E. A. Moritz and associates. Trans. Amer. Soc. Civ. Engin., 74 (1911), p. 411.

No. 5. 6-inch Jointed (Machine-Banded) Wood-Stave Pipe, Sunnyside Project, U. S. Reclamation Service, Washington.—This pipe was built for irrigation purposes about five months before the tests. It is practically straight in both horizontal and vertical planes. Water columns were used for both gauges. Discharge was measured over a 12-inch Cipolletti weir. The capacity of this pipe was about $4\frac{1}{2}$ per cent greater than the discharge computed by the new formula.

Nos. 6, 7, 8. 6-inch Jointed (Machine-Banded) Wood-Stave Pipe, Sunnyside Project, U. S. Reclamation Service, Washington.—This new pipe had been used for irrigation purposes about four months at the time of tests. Alignment and profile were as described for the 8-inch pipe in abstracts for Nos. 9, 10, 11, and 12. Water columns were used at both gauges. Discharge was measured over a 12-inch Cipolletti weir. Usual velocity was about 3 feet per second. Three reaches on the one pipe were tested. The capacity appeared to be about that computed by the new formula.

Nos. 9, 10, 11, 12. 8-inch Jointed (Machine-Banded) Wood-Stave Siphon Pipe, Sunnyside Project, U. S. Reclamation Service, Washington.—This pipe, built for irrigation purposes, had been in use about five months at the time of tests in 1909. Approximately the same reaches were again tested in 1910. Nos. 9 and 11 consist of two tangents intersecting at an angle of $16^{\circ} 40'$ made by a gentle bend with short lengths of pipe. They include the dip in the profile. No. 11 is 120 feet longer than No. 9. Reach No. 12 includes No. 11 with an additional 540 feet of straight pipe on the upstream end. Reach No. 10 is the final 2,002 feet of Nos. 9, 11, and 12, is straight in horizontal alignment, but includes the dip. A remarkable contrast appears in these tests. In 1909 the capacity was about 7 per cent less than that computed by the new formula. In 1910 the tests on the same pipe indicated an apparent increase in capacity to about 20 per cent more than the discharge computed by the new formula, when reach 11 was considered; but reach 12 (which includes No. 11 and is but 15 per cent longer) showed the capacity to have increased to but 5 per cent more than the average. It should be noted that velocities in No. 11 were far greater than those in No. 12. A study of figure 5 fails to show a general tendency toward increase in capacity with age of pipe. The tests on reach No. 11 plot (see Pl. VI) in the zone normally occupied by those on a 10-inch pipe.

No. 15. 10.12-inch Jointed (Machine-Banded) White Pine Pipe,¹ Bonito Pipe Line, El Paso & Southwestern Railway, New Mexico.—This pipe line, part of which is 10-inch and part 16-inch, is more than 100 miles in length and is used in connection with a railway water-supply project. In 1908, 1909, and 1911, J. L. Campbell made tests on both sections. The larger pipe joins the lower end of the smaller pipe at an open standpipe. In measuring velocities the experimenter used bran and colors, accepting the first appearance of the bran or color in computing the period elapsed between the time of their injection and their later appearance. The fact is well known that the velocities near the center of the pipe are higher than those near the perimeter, and thus higher than the mean velocity. Hence if the first appearance of the color is accepted then a velocity in excess of the mean is indicated. In the opinion of the writer this fact accounts for the low friction factor found, and for this reason he did not use these tests in the derivation of the new formula. For additional discussion of these tests see page 11. Had the elapsed time been considered as from the moment of color injection to the mean of its first and last appearance at the outlet, a highly satisfactory series of tests would have resulted. The latter method was employed by the writer and is mentioned by Roy Taylor in connection with tests on the Altmar pipe,² No. 51.

No. 16. 12-inch Jointed (Machine-Banded) Wood-Stave Pipe, Sunnyside Project, U. S. Reclamation Service, Washington.—This pipe was built for

¹ Engin. News, 60 (1908), p. 225; Trans. Amer. Soc. Civ. Engin., 70 (1910), p. 178; 74 (1911), p. 455.

² Engin. News, Sept. 23, 1915.

irrigation purposes in 1910 and had been in use but three months at the time of tests. The line supplements and parallels the pipe described as No. 28. However, the vertical curve at the low point is not so sharp as in the 22-inch pipe. A water column was used for gauge No. 1 and a mercury manometer for gauge No. 2. The diameter was measured at the intake and found to average 12 inches. Discharge was taken over a Cipolletti weir at the intake. The loss of head was abnormally great, capacity being about 15 per cent below the discharge computed by the new formula. Moritz suggests the possible presence of silt in the lower portions of the pipe, as the normal velocity is but 0.8 foot per second and the water is silt-laden.

Nos. 17, 18. 14-inch Jointed (Machine-Banded) Wood-Stave Pipe, Sunny-side Project, U. S. Reclamation Service, Washington.—This pipe for carrying irrigation water had been in use five consecutive seasons when tested in 1909. The reach included in the tests consists of two tangents intersecting at an angle of $32^{\circ} 12'$, where a gentle bend of short lengths of pipe is made. The same reach was tested in both 1909 and 1910. Loss of head appeared less in 1910 than in 1909. This may have been partially due to less friction in the pipe at the later date and partially to mere difference in experimental results. Mercury manometers were used for both gauges. At a place where a stave blew out opportunity was afforded for an examination of the interior of the pipe and for measurement for area in addition to inlet and outlet. At this hole the softer portions of the fir wood had worn away, leaving longitudinal ridges of harder wood. The frictional influence of this condition was problematical. Discharge measurements in 1909 were made over a round-crested weir; those in 1910 were made over sharp-crested weir. In general the 1910 tests should be given more weight than those of 1909. The profile of the line is wavy but without pronounced vertical curve or bends. Three summits are indicated by a ground line profile, but their actual existence in the pipe is questionable. The capacity of the pipe in 1909 was about 9 per cent greater than the discharge computed by the new formula, while in 1910 it was less than 3 per cent greater than that discharge.

No. 20. 14-inch Redwood Stave Pipe, West Los Angeles Water Co., California.¹—Arthur L. Adams conducted a series of seven tests upon reaches of various lengths of a 14-inch redwood pipe supplying the Pacific Branch of National Soldiers' Home, in California. Throughout the length of the pipe line vertical curves were quite numerous, but all were made without the use of "specials" and with radii of not less than approximately 40 feet. Horizontal curves were few, and 286 feet was the minimum radius. The size of the pipe was determined by numerous measurements of external circumference, the thickness of the staves being known to be constant. The discharge was measured with a 4-foot weir whose coefficient was determined by a volumetric measurement. The head on the weir was read on a hook gauge. The loss of head was observed in open standpipes and other designated structures. Points of observation were connected by wye levels. Taking the mean of all the observations on this pipe, the capacity is shown to be about 9 per cent less than as computed by the new formula. This series was used by Williams and Hazen in determining their suggested coefficient of 120. It was also used by the writer in deriving his formulas but was rejected by Moritz.

No. 21. Bonito Pipe Line, New Mexico.—This series is discussed under No. 15 on page 75.

No. 22. Rectangular Unplaned Poplar Pipe.—Tests on an experimental pipe 1.574 feet wide and 0.984 foot deep were made in France in 1859 by Darcy and Bazin.² The discharge was determined by weir measurement and the loss of head by piezometers. This series was used by Tutton in deriving his formula, but was rejected by Moritz and the writer, both of whom considered only round-stave pipes in deriving their formulas.

¹ Trans. Amer. Soc. Civ. Engin., 40 (1898), p. 542.

² Recherches Hydrauliques, Henry Darcy and H. Bazin, Paris, 1865.

No. 23. 18-inch Yellow Fir Continuous-Stave Pipe, Astoria Waterworks, Oregon.—A. L. Adams made two tests on long reaches of new yellow (Douglas) fir continuous-stave pipe. The gravity line supplying Astoria consists of $7\frac{1}{2}$ miles of 18-inch wood-stave, 3 miles of 16-inch and 1 mile of 14-inch steel pipe. The maximum head on the stave pipe is 172 feet. The pipe is buried from 4 to 22 feet deep. Loss of head was observed at standpipes, when the pipe line was carrying maximum capacity. Discharge was measured by the rise of water in a concrete reservoir. Leakage was tested and found to be negligible. The low friction factor found in this test is the more remarkable in view of the fact that there are "in addition to a succession of sweeping horizontal and vertical curves, 27 cast-iron bends, with a radius of curvature of 5 feet, and with an average central angle of about 31° ." (Pl. XIV, fig. 1.) If but two tests at the same velocity are to be accepted as a criterion for the capacity, then the pipe will carry about 17 per cent more than as computed by the new formula. According to Henny this pipe was replaced with redwood in 1911. It had lasted 16 years.

Nos. 24–25. 18-inch Jointed (Machine-Banded) Wood-Stave Pipe, Sunnyside Project, U. S. Reclamation Service, Washington.—This pipe was built in 1908 for conveyance of irrigation water. The reach tested is straight except for one gentle curve through an angle of about 18° . In profile the pipe dips between gauges 1 and 2 about 20 feet in the reach 2,803 feet long. There are three minor summits in the reach. Water columns were used at both gauges. Air pulsations made tests difficult and but one measurement for internal area was possible, this being at the outlet where a distortion of about one-half inch was noted. Discharge was measured over a 6-foot Cipolletti weir and was corrected for leakage through another gate in the outlet structure. The two reaches cover approximately the same stretch of pipe. The capacity of the pipe was about 11 per cent greater than the discharge computed by the new formula.

No. 28. 22-inch Jointed (Machine-Banded) Wood-Stave Pipe, Sunnyside Project, U. S. Reclamation Service, Washington.—This pipe, built in 1906 to convey water for irrigation, had been used four seasons of seven months each at the time of tests. The horizontal alignment consists of two tangents intersecting at an angle of about 5° . The low point of the pipe is about 75 feet below the hydraulic gradient. There are probably no summits. The circumference of the pipe appears to be distorted about 1 inch. Water columns were used for both gauges. Measurements of diameter made at inlet and outlet gave a mean of 22 inches. Discharge was measured for runs 1 and 2 over an 8-foot round-crested weir. The discharge for remaining runs was taken over a 4-foot sharp-crested weir. Seven small leaks were measured volumetrically. Four irrigation hydrants are attached to this pipe. Referring to Plate VI it is seen that some unusual condition must be present in this pipe. Although the mean of all the observations indicates that the capacity is 3 per cent greater than that computed by the new formula, the individual observations indicate that the lowest velocity is 25 per cent greater than the discharge computed by formula, while the highest velocity is 12 per cent less than that discharge, for their respective losses of head. The intermediate velocities show the same trend through the above range. This series was rejected by Moritz, because of the unusual exponent of V . As no really definite reason was given for the rejection, and since other series of various experimenters show nearly as great peculiarities, the writer has retained the series.

No. 32. Experiment H, 24-inch Continuous-Stave Redwood Pipe, Butte City, Mont.—Water for the city of Butte, Mont., is conveyed from a reservoir about 9 miles distant in a redwood pipe laid in 1892 (Pl. XIV, fig. 2), which was designed as a low-pressure line following just under the hydraulic grade line as nearly as topography would permit. However, in some places a head of 200 feet is developed and a great deal of curvature, both horizontal and vertical, occurs throughout the length of

the line. Henny states¹ that too much reliance should not be placed on this test as "the only method at hand to determine the flow was from frequent determination of velocity by means of vertical floats in a semicircular flume at the upper end of the pipe." This test was not used by Williams-Hazen, Moritz, or the writer in the derivation of their formulas. The friction factor found indicates a capacity greater than the average. According to Henny's report in the Reclamation Record for August, 1915, this pipe is still sound "except some deterioration where covered with loose rock only."

No. 33. Rectangular Unplaned Poplar Pipe.—Tests on an experimental pipe 2.624 feet wide and 1.64 feet deep were made in France by Darcy and Bazin. As the pipe is similar to that described as No. 22 the same discussion applies to both. (See page 76.)

No. 35. 31-inch Continuous-Stave Douglas Fir Siphon Pipe, Prosser Pipe Line, Sunnyside Project, U. S. Reclamation Service, Washington.—In the discussion of the Moritz tests J. S. Moore gives the details of experiments conducted by him on the Prosser pressure pipe. Irrigation water is conveyed across the Yakima Valley over the Yakima River in a pressure pipe of combination type. A concrete pipe 30½ inches in diameter is used until the head reaches about 45 feet, at which point the line is changed to a 31-inch stave pipe. The reach tested has but one 5-degree curve, for about 19 degrees of central angle, located near the outlet end. At the river the maximum head is about 105 feet. The tests were conducted in August and October of the first irrigation season after the pipe was finished, the highest velocity being obtained only in August. Before backfilling, but following recinching of bands, external diameters were measured every 50 feet. The discharge was obtained from the rating curve of a 6-foot Cipolletti weir, the curve having been obtained by calibrating the weir against current-meter measurements from a meter station near the weir. The capacity of this pipe was about 6 per cent less than the discharge computed by the new formula. From the fact that the feed canal is down a very steep grade in a natural channel for part of the distance it appears to the writer that the pipe might very easily contain sufficient débris to account for any deficiency in capacity.

No. 36.—This is another reach of the same pipe as that last described. These tests covered a shorter piece, included in the long reach tested as No. 35. The two runs made at the highest velocity, in August, showed the same loss of head per unit of length in both reaches of pipe, but the other runs, made in October, gave divergent results, as shown on Plate VI. Mr. Moore states that he is not prepared to explain this divergence. This series of tests indicate that the capacity is 10 per cent less than the discharge computed by the new formula. (See discussion of No. 35.)

No. 41. 44½-inch Continuous-Stave Douglas Fir Pipe, Municipal Water Supply, Seattle, Wash.²—T. A. Noble conducted a series of tests on a 44-inch pipe at the time the tests on the 54-inch pipe (discussed as No. 44, p. 79) were carried on. With the exceptions noted below the same general methods were used on both pipes. The horizontal curves in the 44-inch pipe were so flat that for all practical purposes the pipe may be considered straight. For about one half the total reach the pipe follows an even gradient. For the other half it crosses a depression about 10 feet in maximum depth in a distance of about 2,000 feet. Thus, practically, the pipe is without curvature in either plane. After passing through the reach of 54-inch pipe discussed as No. 44 the water enters a settling basin. From this basin it is conveyed in the 44-inch pipe now under discussion. Water columns were used for both gauges. Gauge No. 1 was located 150.6 feet downstream from the inside wall of the basin. Gauge No. 2 was located 4,041 feet farther down the pipe line. No growth appeared within the 44-inch pipe; according to Noble the higher velocities in the 44-inch pipe

¹ Journal Assoc. Engin. Soc., 21 (1898), p. 250.

² Trans. Amer. Soc. Civ. Engin., 49 (1902), p. 113.

prevent the attachment of growths. The capacity of this pipe was about 11 per cent less than the discharge computed by the new formula.

No. 43. 48 $\frac{3}{4}$ -inch Continuous-Stave Douglas Fir Siphon Pipe, Mabton Pressure Pipe, Sunnyside Project, U. S. Reclamation Service, Washington.—Under and adjacent to the Yakima River the Mabton pressure pipe is reduced in size from the 55 $\frac{3}{4}$ -inch pipe tested by Moritz and described as Nos. 45 and 46, page 79, to a 48 $\frac{3}{4}$ -inch pipe of similar construction. At the time of the test the pipe had been in operation two and one-half irrigation seasons. During this time the mean velocity had been about 5.4 feet per second. The discharge was measured during the tests in the same way as that used for Nos. 45 and 46. Several diameters were measured at the time similar measurements were made on the 55 $\frac{3}{4}$ -inch pipe. Mercury manometers were used for both gauges. The mean of these three observations indicates that the capacity of this pipe was about 20 per cent greater than the discharge computed by the new formula. This same excess of capacity is shown in the other portions of this siphon, discussed as Nos. 45 and 46. Subsequent to the tests described by Moritz, J. S. Moore experimented upon the portion of the Mabton pressure pipe below the point where the reduction from 55 $\frac{3}{4}$ inches to 48 $\frac{3}{4}$ inches in diameter was made. These tests are all described in the same publication. (See footnote under Nos. 2-3.)

No. 44. 54 $\frac{3}{16}$ -inch Continuous-Stave Douglas Fir Pipe, Municipal Water Supply, Seattle, Wash.¹—T. A. Noble conducted a series of tests for loss of head by friction in the reach of 54-inch pipe between the intake at the dam and the settling basin. As the line follows the sinuosities of Cedar River, it consists of gentle curves joined by short tangents. The minimum radius of curvature is 289 feet. From the appearance of the profile the pipe is laid on an even gradient, with the exception of one slight depression, where a blow-off is located. As a summit is reached after this depression, a 3-inch standpipe is carried above the hydraulic gradient. Holes for the attachment of the piezometers were made by boring with an ordinary wood bit until the tip of the bit pierced the inside of the pipe, making a hole about three-sixteenths inch in diameter. This method was afterwards adopted by Moritz for his experiments. The pipe had been in use about 10 months at the time of test. Gauge No. 1, a water column, was located 232 feet from the intake, while gauge No. 2 was a hook gauge in a well at the outlet of the pipe near the settling basin, 2,446.7 feet below gauge No. 1. The zero points of the various gauges were connected by lines of levels run by three different observers, the mean of the two nearest together being accepted as correct. Noble states that the probable error does not exceed 0.007 foot. The discharge was very carefully measured by an elaborate series of current-meter tests. For this purpose the area of the pipe was divided into four concentric zones, and each zone was covered with a sufficient number of meter readings to develop fully the mean velocity within that zone. In all, the meter was held at 50 points. The interior size of the pipe was carefully measured some two months after the tests. Vertical and horizontal diameters were taken every 100 feet. The resulting figures indicate that the pipe was badly distorted in several places. Growths of *Spongilla* in scattered bunches, each about one-fourth square inch in area and projecting about three-sixteenths inch, were distributed over the inside of the pipe, except along the bottom. The capacity of this pipe was about 2 per cent less than average, probably accounted for by the growth within the pipe; but the 44-inch pipe downstream from this one lacked an average capacity by 11 per cent, with no growth inside.

Nos. 45 and 46. 55 $\frac{3}{4}$ -inch Continuous-Stave Douglas Fir Siphon Pipe, Mabton Pressure Pipe, Sunnyside Project, U. S. Reclamation Service, Washington.—Irrigation water is conveyed across the valley of the Yakima River by a siphon pipe carried under the river. At the intake end water in an open channel passes over an 18-foot rectangular weir into a 54-inch reinforced-concrete pipe. At

¹ Trans. Amer. Soc. Civ. Engin., 49 (1902), p. 112.

the end of about 3,000 feet a head of nearly 60 feet is attained and the pipe changed to a 55 $\frac{1}{4}$ -inch continuous-stave pipe of Douglas fir. A reach of this pipe 2,848.2 feet long was tested in 1909 and again in 1910. At the time of the first series of tests the pipe had been in operation about five months. It was new, well rounded, and contained but minor distortions. There was no deposit or growth inside. Cross-sectional areas of pipe interior were determined by taking four diameters every 200 feet throughout the reach tested. Velocity in the pipe was determined by dividing the discharge, as found by the 18-foot weir, by the mean inside cross-sectional area of the pipe. Mercury manometers were used at both ends of the reach. A comparison of the capacities of this pipe and nearly all other large pipes shows that this siphon is remarkably smooth. This fact is also borne out by the tests on the 48 $\frac{1}{4}$ -inch pipe discussed as No. 43, which is part of this same siphon. This fact is also clearly shown by the relative positions of the points for this pipe in Plate VI. The two series of tests on this pipe were the only ones on any pipe of greater diameter than 18 inches not rejected by Moritz in deriving his formula. This accounts for the difference between the Moritz formula and those of Williams-Hazen, Tutton, and the writer. Giving all weight for large pipes to these two series develops a formula indicating a far greater capacity for large wood-stave pipes than a study of all available tests on such pipes will warrant. If the new formula represents the flow in an average pipe, shown in Tables 2 and 3 to be true, then this pipe will carry more than 18 per cent more water than the average pipe. While conducting tests for the Department of Agriculture the writer visited this pipe after a lapse of four years with a view to securing additional information, but the pipe leaked so badly that tests were not feasible. The pipe was rebuilt in the winter of 1914-15.

No. 49. Moon Island Conduit, Boston, Mass.¹—In October, 1884, E. C. Clarke made one test on a rectangular conduit, flowing full; that is, as a pipe. This conduit is a tight wooden flume 6 by 6 feet, made of planed plank, laid lengthwise. The experimental section was straight, 2,486.5 feet in length. During this test the flow consisted of about one-fourth sewage and about three-fourths salt water. The sides of the conduit were covered with from one-eighth to one-fourth inch of slime below the ordinary flow line. Above this line, on the sides and top, there was some slime but not so much as below the line. Discharge was measured with approximate accuracy by the strokes of the pump pistons. This test was used by Tutton in deriving his formula but rejected by other authorities as the conditions did not parallel those for which the usual pipe is designed.

Nos. 47-48. 72 $\frac{1}{2}$ -inch Continuous-Stave Douglas Fir Power Trunk Line, Pioneer Electric Power Co., Ogden, Utah.²—Soon after the construction of the Ogden Canyon pipe line supplying the Pioneer Electric Power Co. plant, near Ogden, Utah, tests were made by Profs. Marx, Wing, and Hoskins, of Leland Stanford Junior University. These tests covered loss of head in the 6-foot wood-stave pipe and the riveted-steel pipe leading from the stave pipe to the power house. Experiments were first made in 1897³ but were supplemented by a second series of tests in 1899.⁴ In both series the discharge was measured through the Venturi meter installed at the plant. The loss of head was measured by the mercury manometers afterwards used by Moritz in the Sunnyside experiments. The relative elevations of the gauges were determined by the static head in the piezometers with the valves closed so that there was no velocity in the pipe. A constant reduction factor was used in converting the mercury column to the equivalent water column. These experiments have been criticized for this reason, but the writer is of the opinion that no error of moment was thus introduced since, in the tests conducted by him, hydrometer readings were taken

¹ E. C. Clarke. *Main Drainage Works of the City of Boston, Mass.*, 2d ed., 1886.

² *Trans. Amer. Soc. Civ. Engin.*, 38 (1897), p. 246.

³ *Id.*, 40 (1898), p. 471.

⁴ *Id.*, 44 (1900), p. 34.

in all the waters tested, and the variation in specific gravity from that of distilled water was found to be very slight. As it was not practicable to make an examination of the interior of this pipe the nominal size was accepted as correct. It conveys water for several miles down the very rugged canyon spoken of in the discussion of pipe No. 31. Both vertical and horizontal curves are numerous but not excessively sharp. These tests excited much comment at the time for the reason that they were the first to show that a value of about 0.010 for n in the Kutter formula would not apply to all sizes of pipe under all velocities. When compared with all other tests on large pipe, with the exception of Nos. 45 and 46, the capacity of this pipe is shown to be about equal to the discharge computed by formula. Compared to the new formula the capacity is from 5 to 8 per cent less than average. For further discussion of results on this pipe see page 9.

DISCUSSION OF "FLOW OF WATER IN WOOD-STAVE PIPE."¹

By GARDNER S. WILLIAMS, *Consulting Engineer, Ann Arbor, Mich.*; THERON A. NOBLE, *Consulting Engineer, North Yakima, Wash.*; D. C. HENNY, *Consulting Engineer, U. S. Reclamation Service, Portland, Oreg.*; E. A. MORITZ, *Engineer, U. S. Reclamation Service, Denver, Colo.*; E. W. SCHODER, *Professor in Charge of Hydraulic Laboratory, Cornell University*; L. M. HOSKINS, *Professor in Charge of Department of Applied Mathematics, Leland Stanford Junior University.*

Mr. Williams: It may be interesting in connection with the Moritz formula as expressed by the author [formula 9, p. 6]

$$H = \frac{0.38 V^{1.8}}{D^{1.26}}$$

to call attention to the fact that from the experiments of A. V. Saph and E. W. Schoder, published in the Transactions of the American Society of Civil Engineers, vol. 51, the writer derived from the form given at the bottom of page 308 a formula for general use with all kinds of pipe,

$$H = \frac{0.38 V^{1.87}}{D^{1.25}}$$

which, it will be seen, is almost identical with the author's form of the Moritz formula and has been taught to the students of the University of Michigan since 1904.

From the standpoint of exact experimentation slight errors may be expected in the author's results from the method of determining diameters of his pipe. The effect of swelling of the wood in the staves, where they are restrained by the hoops, may very probably change the diameter after they have become saturated from what it was when they were dry.

There is also some question as to the uniformity of the diameters of the glass tubing and the author's practice of reading but one tube of his gauge (as indicated on p. 22) may very likely involve a small error in the head, as in the writer's experience upon careful examination he has never yet been able to find two pieces of tubing that were exactly of the same internal diameter.

¹ Appreciating that the present knowledge of the flow of water in wood-staves pipe is due to careful experimentation and subsequent discussion, carried over a period of 20 years, the original manuscript of the preceding paper was submitted to the above-named men, each of whom has been closely in touch with the development of this knowledge. They were asked for criticism and comment. Acknowledgment is now made of the time and labor expended gratuitously by these authorities in preparing their comments which comprise the discussion given here. Many of the changes suggested by them have been made and to avoid confusion their papers have been therefore edited to conform to such changes.

Throughout this discussion "the writer" will refer to the name heading that particular part of the discussion and "the author" will refer to the author of the paper.

The reference of the author (p. 25) to the watches being exactly set together leads one to infer that a comparison was made at the conclusion of the experiment to determine how closely they had continued to run together. If this was not done there is a possibility of a small error in time due to the varying rate of the watches. It is not an uncommon thing to find two watches to run several seconds apart in the course an hour, although in the course of a day the difference may be inappreciable.

It would add materially to the value of the paper as a record of experimentation if the author would give some details as to the general measurement of the water and also a sketch of the weir used, showing the method of attachment and location of the stilling box. The measurement of the quantity of water is fully as important as the measurement of the loss of head, and it depends upon the precision of the measurement of the head, and upon the accuracy with which the weir is constructed in conformity with previously used experimental examples.

With the information as it stands in the paper it is impossible for one to determine whether the weir measurements are to be relied upon within 2 per cent or within 10 per cent.

The rating of the submerged weir by means of a current meter in a tailrace is perhaps the least accurate experimentation recorded in the paper. The use of a current meter in a tailrace is very unsatisfactory and its indications are liable to be in error anywhere from 10 to 20 per cent. If the wheels in question were reaction turbines it would be possible to get a considerably more accurate determination of the flow by reference to the gate openings and head on the wheels during the test in question. If this were compared with Holyoke tests on similar wheels a determination of the water could probably be arrived at within 3 or 4 per cent.

The investigation of inlet losses described by the author (p. 63) may be subject to error because the distance from the inlet to the place of measuring the head is probably too short. Had the measurement of head been taken 4 or 5 diameters down the pipe it is quite probable that the apparent loss would have been less than that shown at the point where the author observed, by reason of the fact that a contraction of the stream is formed at the entrance which causes an eddy to lie along the wall and this in experiments by the writer was found to extend for some 12 to 15 diameters downstream. The distance to which this might extend, in a large pipe is probably less than that in a smaller one, but it seems questionable if the length of 3 diameters was sufficient to eliminate it even in the large pipes considered.

A statement is made (p. 65) that low discharges entrain more air. This statement is apparently in error. The lower discharges release more air from the water which is flowing through the pipe and hence more air is apparent along the top of the stream and at places where it may accumulate, but rapidly flowing water will absorb and carry with it more air than the more slowly flowing, and this is the reason that the air does not appear at high discharges.

As to the author's comparisons of carrying capacity of wooden-stave and cast-iron pipe it is to be said that the values of the coefficient recommended for different ages in the Williams and Hazen formula are believed by its authors to be very conservative. With the modern coated cast-iron pipe, if well laid, it is doubtful if a coefficient less than 115 will be found at any age unless the coating has been damaged.

In closing it gives the writer pleasure to express his appreciation for the very workmanlike manner in which the observations reported by the author have been conducted.

Mr. Noble: Page 58, line 16, and page 60, line 17. The velocity head and the entry head at the entrance may or may not be lost head, depending upon the shape of the approach to and the exit from the pipe line. This loss may be entirely eliminated by making the first section and the last section of the pipe funnel-shaped, the small end being joined to the pipe in each case. The large end must be sufficiently large that the velocity at the entrance will produce a negligible velocity head (see Francis',

Lowell Hydraulic Experiments, and Clemens Herschel on Venturi Water Meter, published in Trans. Amer. Soc. Civ. Engin., vol. 26, p. 452). This form of entrance and exit also has the advantage of furnishing an accurate and convenient means of measuring the quantity of flow and of keeping track of the gauge height which will not be affected by the condition of the ditch.

Page 5, line 15. In small pipe, from 4 to 12 inches, used for irrigation and waterworks purposes, valves are always used at least in one place, and often a large number of fittings and valves whose effect on the flow is similar to the ordinary gate valve.

In such tests as the writer has made he has found no appreciable loss in any single valve or fitting, but where there are many, as in waterworks systems, the loss on this account is a matter for serious consideration. There does not seem to be much information published that would throw light on this subject.

Page 3, line 5, and page 48, line 35. Attention is directed to the fact that the writer in 1909 first devised this type of formula from suggestions of Messrs. Saph and Schoder. This formula is as follows [Formula 16, p. 48]:

$$Q = 1.28 D^{2.58} H^{0.585}$$

Since that date he has been using this in all his calculations as to the flow in wood pipe. It is in the same form as the one devised by Mr. Moritz and the author. This formula gives results from 0 to 15 per cent less than the author's formula, being about the same for smaller sizes of pipe and 15 per cent less discharge for the larger sizes of pipe. It was the writer's intention in devising this formula to so select the coefficients of D and H that the calculated flow would more nearly approach the quantities of flow determined from tests that were lowest instead of those that were the average.

Page 15, line 27. It is not at all impossible that in a number of the tests on which the formula is based the real average diameter is different from the nominal diameter assumed, due to the following causes:

- (a) Swelling of the wood by saturation.
- (b) Distortion due to imperfect backfilling or settlement where the pipe may have been laid on more or less of a fill, or where there has been more or less leakage.
- (c) Inaccuracy of manufacture. The writer in his examination of a 54-inch pipe found an average of one-half inch larger than the nominal diameter, making a difference of 1.8 per cent increase in the area. This pipe was measured every 100 feet throughout its entire length, from one manometer to the other. In making these measurements considerable distortion was found to exist, and the writer is not certain that these measurements revealed the exact diameter.

Page 46, line 42. It is the experience of most engineers who have had much to do with current-meter measurements that they can not be depended upon to give satisfactory results where the water is at all turbulent or where the cross section of any stretch of the channel is uneven, thus causing considerable turbulence. The greatest care in rating a meter will not help this very large source of error. The error due to turbulence is greater with the Price meter than with the Haskell meter, which latter was used in the writer's experiments on the 54-inch and 44-inch pipe-line tests. The measurements were taken by inserting the meter into the exit end of the 54-inch pipe, being held in exact position by a templet and a pin fastened through the upper end of the meter rod.

Page 47, line 37. The line of maximum velocity within the pipe would be shifted from the center of the pipe to a line close to that portion of the outside of the pipe on which the convex side of the curve occurs. This line of maximum velocity would retain its position for a long distance from the curve and would occur within the length of the pipe tested.

The writer doubts if this abnormal condition would affect the results, particularly if the manometers were attached in the neutral zone of velocity, as the author states was done.

Page 79, line 27. The writer would here call attention to the importance of determining accurately the average diameter at each point of manometer attachment. A very slight difference between the areas at the two points will make a very considerable difference in the results, particularly if the total difference in head between the two points is relatively small. An examination of the data relating to the test of the 54-inch pipe, No. 44 (Trans. Amer. Soc. Civ. Engin., vol. 49, 1902) will show a very considerable change in area throughout the length of the pipe. It was found that the velocity head at any point was exactly proportional to the calculated velocity head.

Page 64, line 40. Same reference is made as for page 60, line 17, as the best means of preventing loss at the entrance and exit. This funnel-shaped entrance prevents the trapping of air at the entrance caused by excessive suction and cross currents, but does not prevent the minute particles of air flowing with the water, or the air that is absorbed by the water, and does not leave it until under a greater pressure from entering the pipe line. Accumulation of air from these causes must be taken care of either by standpipes or automatic relief valves. To leave it in the pipe when there are high points in the pipe line and low velocities is to seriously diminish the flow. It is the writer's opinion that many of the inconsistent results from various tests are due to this cause.

Page 73, line 35. In the case of pipe used for irrigation purposes where the entrance is direct from a ditch, with no adequate settling basin, a considerable quantity of silt, moss, and other débris traveling along the bottom of the ditch finds its way into the pipe line and accumulates in the low points of the pipe, even at velocities higher than 5 feet per second. It becomes settled and packed and slimed over at times when the velocity in the pipe is low. The moss and other vegetable matter tend to bind the silt together into a solid mass, which is not washed out by the higher velocity. This is probably what happened to the pipe line in question.

Page 79, line 31. There were three gauges used in these experiments:

- (a) A hook gauge located at the settling basin or discharge end of the pipe.
- (b) A water manometer attached to the top of the pipe about 150 feet upstream from the outlet end. Sufficient readings were taken at manometer B to make a check on accuracy of using the hook gauge.
- (c) A water manometer located 232 feet downstream from the intake. The area of the pipe at the exit was slightly larger than at manometer B. The head of water at manometer B, less the friction in the pipe line between manometer B and the settling basin, less the difference in velocity head, equaled the head at the settling basin or exit end within the limits of possible error from other causes.

Page 79, line 36. The velocity measurements at the exit of the 54-inch pipe revealed some interesting facts regarding the flow in pipe lines as follows:

First. That the line of maximum flow of water in a pipe line beyond a bend is not in the center of the pipe, but near the outer circumference, and on the same side as the convex side of the curve in the pipe. This would seem to be due to the action of centrifugal force of the water in going around the curve, tending to crowd the maximum velocity toward the outer edge of the curved portion of the pipe.

Second. The average velocity as determined from a number of points distributed systematically throughout the area of the circle of the pipe is the same as the average velocity along either the vertical or horizontal diameter.

Third. The curve of velocity, as near as the writer could determine, is an ellipse where the maximum velocity is in the center of the pipe.

Mr. Henny: The results of the experiments on flow in wood pipe made by the author, under the direction of Mr. Fortier,¹ constitute much needed addition to the

¹ *Author's footnote.*—Samuel Fortier, Chief of Irrigation Investigations, Office of Public Roads and Rural Engineering, U. S. Department of Agriculture.

knowledge on this subject. They are digested and presented alongside of previous experiments in a manner which renders ready comparison possible on whatever basis is most suited to the mental habit as to use of formulas which the reader may have acquired.

The Kutter formula is not adapted to wood-stave pipe, as has been clearly shown by the present as well as by previous authors on this subject. Nevertheless it is used by many engineers and its use is aided to so great an extent by existing tables and diagrams as to leave its intricacy a matter of relative indifference.

The mind, having become used to dealing with it, and its value n , desires naturally to know how the new work now presented, if expressed in the above value, compares with previous conceptions. Moreover, if by means of tabulations it would be possible for any given diameter of pipe and velocity to select the required value of n , the results would conform to the best information available.

The author has developed a new formula, the use of which is sufficiently easy, with the aid of diagrams furnished by him, for practical use. If this were the final word on the subject, it might be convenient and best to discard all other formulas in dealing with wood pipe. In the past, however, various experimenters have been inclined each in turn to work out a formula according to his interpretation of known data, and the future is likely to produce similar results.

If any new formula could be made up which would correctly present the facts, the objection to a possible confusion would not be serious. To what extent the author has succeeded in this regard can be easily judged from his valuable presentation of the case in Plate VII.

This plate shows at a glance the deviation of the results of past experiments from that which would be obtained through the Scobey formula. Its exponential value and constant were determined with a view to minimizing the average of the deviations. Consequently the formula will give results which are as likely to be too large as too small. As will be noted from this plate, the extent of the overestimating of capacity, which its use may involve, frequently exceeds 10 per cent and sometimes reaches 15 per cent (12-inch pipe, experiment 16).

Thus the formula proposed does not give safe results. The extent of its possible error on the side of danger has been increased by the unexpectedly low friction found in the experiments on the White Salmon pipe in the State of Washington (13.5-foot pipe). Expressing the matter in the somewhat more readily understood value of Kutter's n , there appeared in previous experiments a decided tendency to higher values for n with increase of pipe diameter running for 4-foot velocity from 0.010 for 4-inch pipe to 0.0113 for 14-inch, 0.0128 for 36-inch to 0.0133 for 72.5-inch pipe. This tendency is confirmed for lower velocities in experiments with 78-inch pipe. Yet for both the 144-inch and the 162-inch pipe values are now found below 0.012.

It is evident that with further increase of our knowledge on this subject the average must change and that the new average can only be expressed in a new formula in which possibly the exponential value of H may remain close to 0.555, but in which that of D may change as well as the general constant.

The possible error in the direction of overestimating is proposed by the author to be covered by some general factor of safety to be applied in accordance with the injury which may follow from a capacity overestimate. There is excellent merit in this proposition but it, as well as Plate VII, shows the lack of consistency which appears in the nature of the case to attach to the results of various experiments.

Since, therefore, no definite capacity results can be predicted within 15 per cent degree of accuracy, it is somewhat doubtful whether any real advantage can be gained by the construction of a different formula with each addition to our available data.

To the practicing engineer Table 9, showing values of n in Kutter's formula, interpolated from found values for the nearest velocities, may be of use.

TABLE 9.—*Observed values of n for approximately given velocities.*

Ref- erence No.	Pipe diameter in inches.	Location of pipe.	Value of n in Kutter formula—velocity in feet per second.								Kind of pipe.	Kind of wood.	Align- ment.
			1	2	3	4	5	6	7	8			
2-3	4	Sunnyside, Wash.	0.0114	0.0104	0.0100	0.0097					Jointed.	Douglas fir.	Straight.
4	5	do.	0.0108	0.0105							do.	do.	Do.
5	6	do.	0.0102	0.0101							do.	do.	Do.
6	6	do.	0.0105								do.	do.	Do.
7	7	do.		0.0102							do.	do.	
8	6	do.		0.0100							do.	do.	
9	8	do.	0.0116	0.0111	0.0110	0.0107					do.	do.	
10	8	do.		0.0111							do.	do.	
11	11	do.	0.0095	0.0093	0.0093	0.0090					do.	do.	
12	8	do.	0.0102								do.	do.	
13	8	North Yakima, Wash.		0.0115	0.0110						do.	do.	Do.
14	10	do.				0.0113	0.0112				do.	do.	Do.
16	12	Sunnyside, Wash.	0.0128								do.	do.	
17	14	do.	0.0112	0.0110	0.0106						do.	do.	
18	14	do.	0.0108	0.0108				0.0107			do.	do.	
19	14	North Yakima, Wash.	0.0107								do.	do.	
20	14	Los Angeles, Cal.									Continuous.	Redwood.	
23	18	Astoria, Oreg.			0.0101						do.	Douglas fir.	
24	18	Sunnyside, Wash.		0.0109	0.0103						do.	do.	Do.
25	18	North Yakima, Wash.		0.0109							Continuous.	Redwood.	
27	18	Burbank, Wash.		0.0122							Jointed.	Douglas fir.	
28	22	Sunnyside, Wash.	0.0108	0.0123	0.0127						do.	do.	
29	24	Butler, Pa.	0.0131								do.	White pine.	Do.
31	24	Ogden, Utah.			0.0114						Continuous.	Redwood.	
32	32	Butte, Mont.	0.0103								do.	do.	
35	35	Sunnyside, Wash.	0.0134			0.0114					do.	Douglas fir.	Do.
36	31	do.			0.0128						do.	do.	Do.
37	36	Pasco, Wash.		0.0147	0.0132						do.	do.	Do.
38	36	do.		0.0140							do.	do.	
40	40	Burbank, Wash.		0.0118							do.	do.	Do.
41	44.5	Seattle, Wash.				0.0131	0.0129				do.	do.	
42	48	North Yakima, Wash.			0.0104	0.0106	0.0113				do.	do.	
43	49	Sunnyside, Wash.		0.0102							do.	do.	
44	54	Seattle, Wash.		0.0132	0.0126	0.0122					do.	do.	
45	56	Sunnyside, Wash.		0.0110	0.0106	0.0106					do.	do.	
46	56	do.	0.0118	0.0113	0.0110	0.0106					do.	do.	
47	72.5	Ogden, Utah.	0.0150	0.0136	0.0133	0.0132					do.	do.	
48	72.5	do.									do.	do.	
50	78	Ephratah, N. Y.									do.	do.	
51	144	Albany, N. Y.	0.0165	0.0130	0.0131			0.0120	0.0124	0.0124	do.	do.	
52	162	White Salmon, Wash.				0.0116	0.0116	0.0116	0.0116		do.	do.	

NOTE.—Alignment where marked "straight" may contain small percentage of slight curvature. Where not marked the alignment contains considerable percentage of curvature, usually both horizontal and vertical. In a few cases the alignment was not ascertainable from the records.

The causes of the large deviations in the constants of any formula so far proposed have been the subject of frequent discussion. The varying amount of curvature is undoubtedly one of these causes, and its separate effect upon resistance may well engage the attention of experimenters. Age appears generally to have little effect on carrying capacity of wood pipe. Errors in the experiments themselves are becoming smaller with greater refinement and the use of coloring matter in determining the velocity directly may be considered as a distinct advance. The main reason for the apparently arbitrary variations probably lies in the difference in smoothness of the interior surface, which may be due to vegetable growth, effect of wear, variability of the wood, and in some measure to workmanship. So long as it is not practicable to specify and insure a known degree of smoothness, so long will the application of judgment be necessary in the use of any formula.

Entry head is due to eddy currents above and below the point of entry. The loss due to eddy currents in the intake basin is very variable, depending upon the lines of approach which at times favor the formation of whirls and vortexes. This item of loss is, however, relatively small and may generally be neglected. The loss below the point of entry is due to an uneven distribution of velocity throughout the section immediately below the point of entrance.

The area so far as it is occupied by rapidly forward-moving water is contracted as in the case of open-air discharge, although under conditions of counterpressure probably to a smaller extent. The area between the contracted section and the pipe shell is a cavitation space which may be filled with eddying water or may become under high-velocity discharge a complete vacuum. The energy of the moving water in the contracted area is greater, due to higher average velocity, than in the moving water farther down the pipe, the difference being destroyed by internal friction and constituting the principal part of entry head.

Where the assumption is made by the author that $h_e = \frac{1}{2} h_v$, it is equivalent to assigning a constant value of 0.82 to the coefficient of contraction. While this assumption is not unusual it must be evident that this coefficient must be largely affected by conditions of velocity, depth of pipe entrance below water surface, shape of intake basin and elevation of floor with reference to pipe invert.

Table 6, presented by the author on this subject, yields no positive information. The influence of velocity of approach is neglected, which may be permissible in cases such as tests 7 and 8 where the outlet is at right angles to the direction of approach, but is not correct in tests 5 and 6 where the flow is straight toward the entrance. The table gives results which are erratic, as might be expected. For tests 7 and 8 it indicates that the entry head equaled $0.89 h_v$ and $0.63 h_v$, respectively, instead of $0.50 h_v$, equivalent to coefficients of contraction 0.73 and 0.78, respectively, instead of 0.82.

The usual assumption of 0.82 as the coefficient of contraction, or $\frac{1}{2} h_v$ as the entry head, may be justified in some cases, but will at times lead to serious error. (See also, Merriman's Hydraulics, 9th ed., p. 214.)

Mr. Moritz: It will generally be conceded on the basis of the showing made in this paper that the new formulas proposed fit all observations so far made on wood-stave pipe better than any other formula heretofore offered. The problem is, however, not susceptible of cold-blooded scientific analysis and the personal equation of the analyst must necessarily affect the ultimate result. The present paper can not be considered as the final answer to the problem of flow of water in wood-stave pipes and in view of the close agreement between the author's formula and others that have been used, the writer is not satisfied that there is sufficient justification for a radical departure from formula constants that have been well established and accepted. The writer has in mind especially the exponent of d which for upward of 10 years or more has stood unchallenged at 1.25 and this figure has been accepted by such well-known hydraulicians and experimenters as Dr. E. W. Schoder, of Cornell University, and

Gardner S. Williams, formerly of Cornell and Michigan Universities, as representing the best average value. They inclined rather toward varying the exponent of V within the range of about 1.75 to 1.95 and they also varied the coefficient m for different kinds and conditions of pipes from about 0.30 to 0.50.

The exponent 1.25 was determined by Schoder from a plotting of all known observations on pipes covering the entire field from very small drawn-brass pipes to very large tuberculated riveted-steel pipes, and is therefore not based on estimate nor opinion, but on actual facts.¹ The writer's observations on wood-stave pipes developed a value of 1.26, which he has since reduced in the formula for practice to 1.25 to conform to the generally accepted figure.

In the matter of proposing a new formula, the writer lives in a glass house and can therefore not afford to throw stones. However, there were extenuating circumstances in this case, which need not be discussed here, that ultimately led to a rather wide acceptance of the writer's formula, although he originally offered it with reservations because there were a number of points not satisfactorily explained, and experiments on very large pipes were notably lacking. Thanks to the author's careful experiments the deficiency has now been supplied to a considerable extent and we are closer to the ultimate solution.

It is interesting to note that the author has arrived at the same figure for exponent of V , namely 1.8, that developed from the writer's experiments. Unfortunately, he had not time to check the author's analysis on this point, nor to make an independent analysis of the data in this paper, but the evidence in support of this average figure may now be fairly considered as having been greatly extended. The evidence in support of 1.25 as the exponent of d is in the writer's opinion equally as good if not better, since its derivation was based on observations on all kinds and sizes of pipes.¹ If we could, therefore, now agree on these two figures and throw the variation in formula for different classes of pipe into the factor m , a much longer step will have been made toward the general acceptance by engineers and courts of an exponential formula for flow of water in pipes.

It must be conceded that additional experiments that may be made in the future, especially in the field of diameters between 60 and 160, may have a marked effect on the exponent of d and we will then no doubt be confronted by another formula. Moreover, as has already been pointed out, the personal equation of the analyst, especially in the application of weights and methods of reasoning, must be taken into account and another person with the same data as a basis would no doubt arrive at somewhat different conclusions than those given in the present paper. No doubt this factor has been eliminated to the greatest possible degree in the present paper, but complete

¹ *Author's footnote* (the italics are his).—A study of original sources does not bear out this statement. In Trans. Amer. Soc. Civ. Engin., vol. 51, Messrs. Saph and Schoder, on page 305, state: "First of all, the line best fitting the points for the writers' brass pipes has been drawn," which line, as they say on page 306, "forms the lower limit of the zone in which all the plotted points lie. This is another way of stating that these pipes represent the extreme of smoothness and ideal conditions." The exponent of d for this line was found to be 1.25. (This line is A, fig. 7.) The values of m for all kinds of pipes were then plotted and Saph and Schoder state (id., p. 308): "It will be seen that a line parallel to the one already drawn will represent fairly the other limit" of the zone. (This line is shown as B, fig. 7.) Thus it will be seen that this exponent was derived from a study of *smooth brass pipes* and then *applied to all kinds of pipes* by drawing a line parallel, i. e., with the same slope, hence indicating the same exponent of d , or 1.25. In discussing the exponent as derived by Saph and Schoder, Mr. Allen Hazen states (id., p. 321), "It is, unfortunately, a fact that probably none of the large pipe has as *smooth surfaces as the brass pipe used by the authors* (Saph and Schoder) and some allowances must be made for this fact in the comparisons, and, while the line drawn as a general average would be a matter of individual judgment, the writer (Hazen) would hardly give it *an inclination greater than that corresponding to an exponent of 1.20*. If the matter were carried further the exponent would probably be lower." It is interesting to again note that the exponent of d is 1.17 in the formula derived from a study of these same pipes of all kinds by Williams and Hazen, and that this is the same exponent found in this study of the flow in wood-stave pipes. (Line E, fig. 7. This question is further discussed on page 94.)

elimination of the same is impossible, and this fact should be taken into full account when the proposition of offering a new formula is considered.

With the above ideas in mind, the writer has examined figure 4, from which the exponent of d and the coefficient of m have been developed. He assumes the point in the center of the diagram with the two concentric rings represents the center of gravity of all the points, taking into account the assumed weights, and that the points on either side of the center with one concentric ring represent the center of gravity of all the points on the respective sides. He has drawn a line (A, fig. 4) through the central point on a slope of 1.25, which gives an intercept of 0.43. If this be accepted,

the formula becomes $\frac{H=0.43}{d^{1.25}} v^{1.8}$ which gives velocities and consequently discharges that are about 7.6 per cent smaller than those given by the writer's formula $\frac{H=0.38v^{1.8}}{d^{1.25}}$.

If the figures in column 20 of Table 3 are now corrected by the addition of 7.6, the "grand average per cent" of deviation of the observed velocities from those calculated from the above formula becomes 0.04. On its face this would seem to indicate that this formula is more accurate than the Scobey formula, which is not necessarily true, and this leads the writer to remark that the deductions at the foot of this table are misleading.¹ The same remark applies to Table 2. However this may be viewed, he thinks a better comparison of the formulas could be presented by grouping the observations or pipes by percentage deviation from each formula, somewhat as follows:

TABLE 10.—Comparison of observed velocities to velocities computed by various formulas.

Author of formula.	Number of observations differing by given per cent.							
	Less than +5.	+5 to +10.	+10 to +15.	+15 to +20.	+20 to +25.	More than +25.	Less than +10.	Less than +15.
Scobey.....	30	24	19	20	8	5	54	73
Williams-Hazen.....	44	30	24	16	14	8	74	98
Moritz.....	43	12	5	6	1	0	55	60
Tutton.....	42	39	36	20	4	11	81	117
Weisbach.....	37	20	6	4	5	1	57	63

Author of formula.	Number of observations differing by given per cent.							
	Less than -5.	-5 to -10.	-10 to -15.	-15 to -20.	-20 to -25.	More than -25.	Less than -10.	Less than -15.
Scobey.....	46	48	39	12	1	2	92	131
Williams-Hazen.....	49	40	16	9	1	2	89	105
Moritz.....	29	18	42	49	41	8	47	89
Tutton.....	46	40	13	11	1	5	86	99
Weisbach.....	29	36	30	39	14	11	65	95

The writer is convinced that his formula should be modified to the extent of increasing the coefficient m from 0.38 to 0.43, which will reduce the calculated carrying capacities by 7.6 per cent. He is not convinced that the exponent of d should be

¹ *Author's note.*—The line A (fig. 5) or any other line drawn through the center of gravity will give a formula in which the "grand average per cent" will be very close to zero as the moments of the various individual points neutralize each other, the percentages for all pipes on one side of the center of gravity being too low and for those on the other side too high. The heavy line in figure 5, representing the author's formula, is the only line that satisfies not only the "grand average per cent" but also satisfies similar comparisons for only those pipes above the center of gravity or those below the center of gravity. This is true because this line is the only one that can and does pass through the center of gravity of all points and likewise through the centers of gravity of the points in the two zones into which the main center of gravity divides all points. Viewed in this light the deductions at the foot of the columns mentioned are not misleading.

reduced from 1.25 to 1.17 until the field of larger pipes has been more fully covered.

The formula $\frac{H=0.43}{d^{1.25}} v^{1.8}$ gives practically as correct results as the author's formula and conforms much better with the results developed by previous experimenters.

It is conceded that the arguments presented herein are rather unscientific, but we are dealing with a problem that is more practical than scientific, and expediency should be given as much weight therein as science. The engineer should not strive for an impossible accuracy or an artificial consistency in his essentially practical operations. The writer feels that the author would be doing the engineering profession a greater good if he would depart to a smaller extent in his formula from the factors that have been developed by other experimenters before him.

Dr. Schoder: After the first reading of the paper the writer is inclined toward a somewhat detailed discussion of numerous points that seem open to reasonable differences of opinion. However, after again reading the paper, most of these points seem to be aside from the main argument that is advanced somewhat directly and somewhat by implication in the paper. Consequently the writer's comments will deal rather with the question it seems proper to ask: "Does the paper sufficiently emphasize the relations of the facts therein established for wood-stave pipes to the facts for pipes of *all materials*?"

This suggests the query: "Is a special formula for wood-stave or any other particular material proper or practically desirable in the light of information now before the engineering public?" The author's paper is a very important contribution toward such information. It remains to make the general examination and comparison suggested.

Concerning the new data gathered by the author, the writer would sum up his estimate and appreciation: (1) The field difficulties were many and serious. (2) The measurements, in the main, appear to be reliable.

Comparison of the data on wood-stave pipes with the data on pipes of all materials. The author states (p. 51) that the exponent of the velocity ranges from 1.56 to 2.31 and that he is unable to find any law for this variation for the wood stave pipe data. It is interesting to examine these exponents as given in the nicely arranged Table 3.

1"-10"	12"-24"	30"-162"
1.723	1.738	1.56
1.895	1.730	1.67
1.808	1.870	1.70
1.877	1.703	2.31
1.847	2.176	1.719
1.724		1.696
1.590		1.747
1.766		1.618
1.875		1.973
		1.690
		1.891
		2.143

It seems to the writer that "confusion" will be worse confounded" by the apparent sanction of a United States governmental department to a formula and diagrams or tables based thereon, particularly applicable to wood-stave pipes, when the data, according to the author's own statements of factors of safety on page 66, and particularly in column 19 of Table 2, show such large departures from the results by the formula, and when there is nothing in the data on wood-stave pipes that distinguishes such pipes from the data on iron, steel, brick, concrete, or other pipes.

In other words, if all the data presented on wood-stave pipes are plotted on Plate XI, Trans. Amer. Soc. Civ. Engin., vol. 51, or on figure 2, Cornell Civil Engineer, May, 1910, or even if the data for all steel and iron pipes be added to the author's figure 4, the conclusion seems to be irresistible that the pipes used in engineering practice for the conveyance of water can not be segregated, as to hydraulic resistance

to flow, into the particular materials of which the pipes are constructed, except in sharply limited cases where the material is a measure of the roughness.

The writer considers the author's formula as *good and as safe as any*, if its limitations as shown by column 19, Table 2, be taken into account and if the velocity in the pipe under design is not much greater than in the data presented in Table 2.

This suggests the difficulty in getting the engineering public to recognize the *average quality* of an averaging formula. Thus the significance of the formulas on page 309, Trans. Amer. Soc. Civ. Engin., vol. 51 (1903), is very liable to be overlooked when presented in the form given on page 281, Eng. Rec., September 3, 1904.

Unless these general interrelations of *all pipe flow data* are specifically emphasized, it seems that a good opportunity will be lost. The author states on page 50, "However, in deriving the new formula, tests made on round, wood-stave pipe only were considered, in view of the proposed use of such a formula." The inference that data on other pipes are not relevant will be drawn from this by the great body of readers. Thus the error so long perpetuated by hydraulic texts will be given apparent sanction.

From a purely selfish viewpoint the writer would not be eager to see the author's paper broadened as suggested. It furnishes data to drive home matters about which there have been great uncertainty in the minds of a few, and general ignorance in the minds of the many who place a halo about textbook formulas. If the author does not, others will do it.

The value of the paper as it stands is great. It is in the hope that the author may be persuaded to make the shift in viewpoint necessary to add much to the permanent value of his deductions that the writer ventures these comments.

In The Cornell Civil Engineer of December, 1911, page 127, there are some data that may be found of interest in connection with the author's method of finding velocities by injecting a colored solution into the pipes and timing the interval from the instant of injection to midway between the first and last appearances of color downstream.

Prof. Hoskins: The experimental work described in "The Flow of Water in Wood-Stave Pipe" is a valuable addition to knowledge on the subject, and the author's summary of conclusions appears to merit confidence as embodying present knowledge on the hydraulics of wood-stave pipe. The exponential formula adopted as the result of the discussion is probably as reliable a

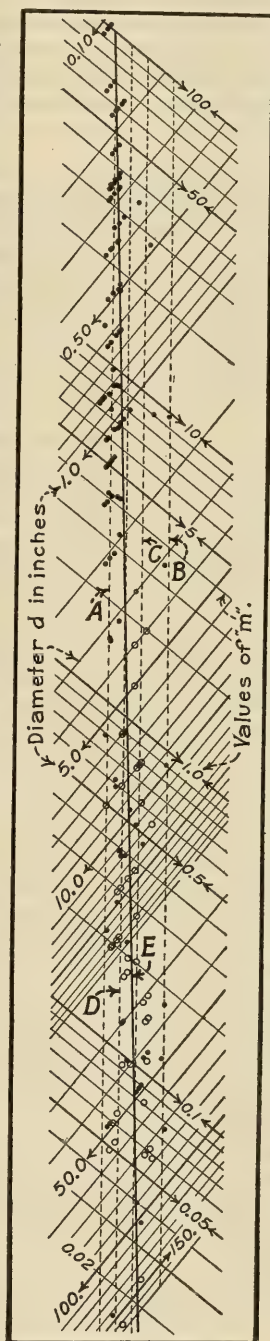


Fig. 7.—Comparison of curves for exponent of d . Line E based on values of m' for experiments on wood pipe, shown by circles (also see fig. 4). Dotted lines suggested by Saph and Schoder for many kinds of pipes, for which values of m are shown as dots.

guide as the present state of knowledge makes possible. The writer thinks all who have been concerned in experimental work of this character must recognize that a close approach to exact agreement among results is not to be expected. The author's analysis of the conditions affecting the reliability of the experiments is very thorough and his work seems to merit acceptance equally with the best previous results. Nothing occurs to the writer by way of criticism or discussion worthy of publication.

Author's closure.—The apparent lack of conformity in results of hydraulic experiments has discouraged many observers. It would appear that carefully conducted experiments, made with the best of apparatus, should give results of extreme consistency. It is more than likely that results that should be consistent are so and that variations are due to influences that can not be seen or guarded against. The best that may be done is to anticipate all known abnormal conditions and either eliminate them or make corrections for them.

Discussions of some experiments mentioned appreciated field difficulties. There is a vast difference between testing small pipes, weirs, or other devices in a hydraulic laboratory, where all of the factors are assuredly in the control of the observer, and testing large commercial structures in the field under varying weather conditions with unavoidable fluctuation in discharge of water and other difficulties that may or may not come to the knowledge of the experimenter during the tests. Seldom it is that a field layout approaches ideal conditions for experimentation. Except in rare cases tests of commercial plants must be foregone if laboratory conditions are to be met. When apparatus is set up for test in a laboratory, minute measurements of diameters, water volumes, and other factors may be made. Both interior and exterior may be examined with microscopic care. In field tests of pipes, on the other hand, it is not often that water may be withdrawn for sufficient time to enable the experimenter to fully acquaint himself with conditions that are ordinarily hidden.

Probably the most accurate series of tests of record are those conducted by Saph and Schoder on brass pipes. The largest of these was slightly more than 2 inches in diameter. With all the accuracy the experimenters could bring to bear upon these tests in a hydraulic laboratory, the results were such that they qualified their derived formula with a factor of ± 7 per cent.¹

When the above qualification is necessary for a formula based on laboratory tests on pipes having uniform structural characteristics which have never been subjected to deposits, growths, or tuberculations, what is to be expected of a formula for use in the design of wood-stave pipes based on pipes taken as they come in the field? Can such a formula show more than the new formula shows in Table 2 and on Plate VII? Except in isolated cases this agrees within ± 15 per cent with more than 250 observations on 52 pipes from 1 to 162 inches in diameter. Furthermore, more than half of these pipes are siphons on irrigation projects; that is, pipes inserted between open sections of canal from which all manner of trash, silt, and rock ravelings may enter the pipe and retard the flow. These are unavoidable conditions in the operation of such pipes, and the author would not confine his tests to pipes under more nearly ideal conditions, even if such might be chosen. These conditions must be anticipated by the designer and some suitable factor of safety introduced as is suggested on page 66.

The above is not offered by way of apology for the new formula but to make clear the fact that the actual discharges from pipes designed on the basis of the new formula are not to be expected to agree with the formula values exactly but only to a reasonable degree.

The author agrees with Mr. Williams and Mr. Noble that experimental errors, due to erroneous assumptions of pipe diameter, may creep into the results. These errors

¹ Trans. Amer. Soc. Civ. Engin., vol. 51 (1903), p. 306.

may involve a change in velocity head or be due to an incorrect mean area of the pipe being taken, and consequently an incorrect velocity used in a given test, if the indirect method of measuring the velocity is employed. The fact that the interior of most pipes tested in commercial service can not be examined means that the nominal diameter of a pipe must in many cases be accepted or that no experiments be made. The reverse of this problem confronts the designer. He must make computations on the basis of a given size of pipe, whereas the pipe when actually built may vary slightly from the designed size.

No appreciable error was introduced by reading but one gauge glass of a U-tube manometer at a time. It must be remembered that before reading the pressure was so throttled that the mercury was barely "alive." This means that in either gauge glass the "breathing" of the mercury did not extend over more than two or three thousandths of a foot. Any error of reading due to a difference in the size of the tubing, as questioned by Mr. Williams, would be so small a part of these two or three thousandths of a foot as to be negligible. Reading alternate legs of the manometer and computing the leg not read would tend to neutralize any error that did exist, remembering, of course, that *both* legs were "dead" columns of mercury, at intervals of approximately 10 minutes.

In answer to Mr. Williams's question as to comparing watches after the tests, the author would say that this was done and any necessary corrections of a few seconds was immediately noted in the field notes. Many experimenters are very careful to conduct all work with a stop watch. These watches may be read to a nicety but can still be inaccurate unless most carefully adjusted with a chronometer. This is quite evident if several of them be started together and compared at the end of an hour.

Additional information on the weirs used has been written into the original text or shown in the views in conformity to Mr. Williams's suggestion.

The accuracy of the meter calibration of the Altmar weir in connection with the tests on pipe No. 51 is questioned by both Mr. Noble and Mr. Williams, for the reason that the meter measurements must be made in the tailrace. As shown by figure 2, Plate V, the water downstream from the weir was not turbulent. When the gaging bridge was reached several hundred feet downstream from the weir, the water was flowing evenly and smoothly. The channel is excavated in flat, rather level strata of rock, and the four meter gaugings conform so closely with an even curve that the author does not believe any undue error was made. The verticals in which the meter was held were sufficient in number so that the section was well covered. The mean velocity of the channel was but 3.25 feet per second for the greatest discharge measured. Such a velocity in a relatively smooth channel will not produce turbulence.

Regarding the experiments on loss of head at entrance to pipes, Mr. Williams apparently misunderstands the author. The loss of head was not *observed* at a point *three* diameters down the pipe but at a point *several* diameters down the pipe, and the loss between the inlet and the 3-diameter point was *computed* by deducting the friction loss per foot for the number of feet *back* from the point of observation to the 3-diameter point; thus finally the net loss from the intake to the end of a short tube 3 diameters long was deduced.

Regarding the entrainment of air: A large proportion of the wood pipes used in irrigation practice are on inverted siphons between sections of open channel. When such a pipe is running at full capacity the inlet is usually well submerged and but a moderate amount of air is caught and carried into the pipe. When the pipe is carrying but a small part of its capacity the water rushes down the intake end and generates a violently turbulent condition just where the pipe is filled. The impact of the water rushing down the intake at high velocity causes many air bubbles to be carried into the pipe. Obviously, as suggested by Mr. Williams, a pipe at full capacity

would carry more air were the same opportunity offered at the intake for its entrainment.

Concerning the various factors of the new formula: From the discussion it appears to be granted that this formula fits the basic observations better than any other formula. It should, of course, do this as it is an *averaging* formula based on all known observations. Two questions now arise: Should an *average* formula be used and should factors in new formulas be allowed to digress from time-honored factors in accepted formulas? If we do not accept an average formula we must do one of two things. The first is to accept a formula that will give the most conservative results. Such a formula for wood-stave pipe would be probably 25 per cent more conservative than the new formula or 40 per cent more than the Moritz formula, if all observations on wood-stave pipe are to be included. If we exclude any tests as abnormal we find it hard to draw the line—hard to find any tenable intermediate ground between the average and the extreme. The other method that may be pursued is to follow Schoder¹ and Moore,² and give the bounding limits for any particular factor, stating these limits as a variable feature of the formula.

Unfortunately the practice of the average engineer is so general that he does not become qualified, nor has he the time, to properly choose the correct figure between the varying limits. He would rather that the one most familiar with the variables give him one formula without varying coefficients or exponents and with a statement as to its approximate accuracy. This was recognized by Moritz.³ In the opinion of the author the averaging formula appeared best when used in connection with the suggested factors of safety. (See p. 66.)

Mr. Moritz's suggestion that the exponent of d or D in the new formula violates accepted exponents in parallel formulas does not appear to the author to be well taken when studied in connection with figure 7, which shows the same plotted points for wood pipe experiments as figure 4, and which in addition shows by small round dots the values of m for all the experiments given on Plate XI, Trans. Amer. Soc. Civ. Engin., vol. 51, "The Flow of Water in Pipes," by Saph and Schoder. These additional experiments are on various kinds of pipe, including brass, galvanized-iron, wrought, sheet, and cast-iron, brick, glass, lead, and riveted pipes. In figure 7, line A, is Saph and Schoder's limiting line for "very straight and very smooth pipes" with the equation $m = \frac{0.296}{D^{1.25}}$. Line B is their limiting line for tuberculated pipes, with

the equation $m = \frac{0.687}{D^{1.25}}$. These writers then state that most pipes in commercial use

will plot between lines A and C, the equation of the latter being $m = \frac{0.469}{D^{1.25}}$. As the values of the exponent of V vary from 1.74 to 2.00 the general equation showing the variation between the lines A and C becomes $H = \frac{0.296 \text{ to } 0.469}{D^{1.25}} V^{1.74 \text{ to } 2.00}$.

Note that equation $H = \frac{0.38 V^{1.87}}{D^{1.25}}$ mentioned near the beginning of Mr. William's discussion on page 81 takes the average of these variants, $m = \text{line D}$, figure 7, while Dr. Schoder⁴ in 1904 suggested exactly the same formula except that the exponent of V was given as 1.86 instead of 1.87. (See column 6, Table 10.)

Again referring to figure 7, line E shows the author's curve, $m' = \frac{0.419}{D^{1.17}}$ or $\frac{7.68}{d^{1.17}}$. Note how closely this line on a slope of -1.17 conforms to the plotted points for all

¹ Trans. Amer. Soc. Civ. Engin., 51 (1903), p. 308.

² Id., 74 (1911), p. 471.

³ Id., p. 478.

⁴ Eng. Rec., Sept. 3, 1904, p. 281.

kinds of pipe, and note also that *Williams and Hazen found this slope for all kinds of pipe to be -1.167 (practically -1.17) as shown in formula 8a, page 6.* Furthermore, by reference to pages 4 to 7 of their tables¹ and to the plotted points in figure 7, or to Plate XI in volume 51 of the Transactions of the American Society of Civil Engineers, it will be seen that Williams and Hazen found this exponent of d and D to be 1.167 from exactly the same experiments, except for a few additions, as those that were included in a zone bounded by two lines (A and B, fig. 7) at a slope of, and indicating an exponent of, 1.25 by Messrs. Saph and Schoder, while the author found a value of 1.17 when experiments on circular wood pipe alone were considered. As shown in the author's note on page 88, the exponent of 1.25 was determined from a study of smooth brass pipes.

Summing up, it does not appear from the above study that a value of 1.17 for this exponent of the pipe diameter based on a line plotted through the centers of gravity for all values of m' in wood-stave pipe experiments is at variance with accepted values of this exponent for flow in all kinds of pipe, as typified by the Williams-Hazen general formula.

Dr. Schoder suggests that this paper be broadened to compare "the facts herein established for wood pipes to the facts for pipes of all materials."

In the author's opinion, however, the structural characteristics and the methods of making joints in pipes of the various materials are so different that it will be extraordinary indeed if any one formula can be found to even approximately fit all kinds of pipes. The author believes that such a comparison and conclusions therefrom would be premature at this time, especially in view of the meager information now available concerning the flow in pipes of cement and concrete materials, which are being used more and more for permanent pipe construction.

In order that a final comparison may be made of various formulas, as suggested in the discussion, the writer has prepared Table 11, which shows the computed velocities by various formulas for given sizes of pipe and given losses of head. The general deduction may be made from a study of this table that it makes little difference which of these formulas is used in the design of pipes up to 12 inches in diameter, with velocities up to 4 feet per second. As larger pipes and higher velocities are involved, the divergence between velocities as computed by various formulas becomes greater and greater. For instance, a loss of head of 1 foot per 1,000 feet of 12-foot pipe will generate a velocity of 9.74 feet per second, according to the Moritz formula, or 50 per cent more than the velocity computed by the Swickard formula, although the latter was developed for the most part from a study of the Moritz data.

¹ Hydraulic Tables. Williams and Hazen. New York, 1909.

TABLE 11.—*Comparison of velocities, in feet per second, as computed by various formulas, for given sizes of pipe with given friction heads.*

Diameter.	Friction head, H.	Velocity per second by formulas.					
		Scobey.	Williams-Hazen.	Moritz.	Schoder.	Swickard.	Noble.
<i>Inches.</i>	<i>Feet.</i>	<i>Feet.</i>	<i>Feet.</i>	<i>Feet.</i>	<i>Feet.</i>	<i>Feet.</i>	<i>Feet.</i>
6	2.0	1.52	1.48	1.58	1.54	1.49	1.63
6	5.0	2.52	2.45	2.60	2.52	2.35	2.80
6	9.0	3.50	3.39	3.57	3.46	3.20	3.97
12	1.0	1.62	1.60	1.72	1.67	1.65	1.63
12	5.0	3.95	3.78	4.20	3.98	3.85	4.19
12	9.0	5.48	5.16	5.82	5.50	5.10	5.90
36	.2	1.35	1.32	1.52	1.48	1.50	1.20
36	1.0	3.30	3.15	3.71	3.50	3.45	3.06
36	5.0	8.05	7.50	9.06	8.30	7.80	7.90
72	.2	2.12	2.06	2.46	2.34	2.25	1.79
72	1.0	5.18	4.89	6.02	5.55	5.00	4.62
72	2.0	7.60	7.14	8.85	8.00	7.20	6.91
96	.2	2.56	2.46	3.02	2.86	2.55	2.13
96	.6	4.70	4.46	5.55	5.15	4.45	4.04
96	1.0	6.25	5.82	7.37	6.70	5.60	5.44
120	.2	2.96	2.84	3.53	3.30	2.80	2.42
120	.6	5.44	5.14	6.49	6.00	4.85	4.60
120	1.0	7.25	6.73	8.62	7.90	6.00	6.20
144	.2	3.32	3.18	3.97	3.75	2.95	2.69
144	.6	6.10	5.75	7.35	6.70	5.10	5.10
144	1.0	8.15	7.58	9.74	8.95	6.40	6.89

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Contribution from the Bureau of Entomology
L. O. HOWARD, Chief

Washington, D. C.

PROFESSIONAL PAPER

August 18, 1916

THE ARGENTINE ANT:¹ DISTRIBUTION AND CONTROL IN THE UNITED STATES.

By ERNEST R. BARBER, *Scientific Assistant, Southern Field Crop Insect Investigations.*

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INTRODUCTION.

The Argentine ant² is one of the most serious of household pests. Any exposed food or food refuse in the infested sections attracts the workers of this species in abundance, and residents and keepers of grocery stores, meat markets, confectioneries, etc., must either suffer considerably or almost constantly use poison or barriers of various kinds. If its activities were confined to the household only, the problem of controlling the Argentine ant would be sufficiently difficult, but in common with some other ants it has the habit of protecting mealybugs and aphids and thus indirectly becomes a pest of crops.

The problem is more serious from the fact that the species is steadily spreading in all directions throughout the Southern States. It is practically certain that it was introduced into this country at New Orleans, in ships which brought coffee from ports in Brazil, although the exact date of this introduction will always remain in doubt.

The Argentine ant was first observed in New Orleans in 1891 by Mr. Edward Foster.³ At that time he records it in small numbers:

¹ The work of the Bureau of Entomology on the Argentine ant is divided into two parts. One part deals with the ant as a general pest, its distribution, and relation to the cultivation of sugar cane. The other part relates to the special problem of control in citrus groves. This phase will be treated in another publication. The work reported in this paper does not include reference to conditions in California, parts of which State are also infested by the Argentine ant.

² *Iridomyrmex humilis* Mayr.

³ Foster, E. The introduction of *Iridomyrmex humilis* (Mayr) into New Orleans. Jour. Econ. Ent., v. 1, no. 5, p. 289-293. 1908.

nine blocks east of the wharves at which the coffee ships usually discharged their cargoes. It may be surmised, from the knowledge we have since gained from studying the natural dispersion of this insect, that it has been in the country for about 45 years. During that period it has expanded from the original colony to myriads of colonies, extending its area of distribution into nine Southern States, the many infestations covering a total area of considerably more than a thousand square miles.

PRESENT KNOWN DISTRIBUTION IN THE SOUTHERN STATES.

Newell and Barber,¹ writing in 1913, recorded the known distribution in the Southern States as confined to Louisiana, Mississippi,



FIG. 1.—Map showing the distribution of the Argentine ant in 1913 (inner line of small dashes) and at the end of 1915 (outer line of longer dashes). (Original.) The outer line has been drawn merely to connect the outlying points. It includes some territory in which the ant is not known to occur, as, for instance, western Florida.

and Alabama, and established the limits of this dispersion from Montgomery, Ala., on the east, to Lake Charles, La., on the west, a distance of 380 miles, and from Delta, La., on the north, to the mouth of the Mississippi River, a distance of 250 miles. At the present time the limits of the distribution are from Houston, Tex., on the west, to Wilmington, N. C., on the east, and from Nashville, Tenn., to the mouth of the Mississippi River, a distance of 1,100 miles east and west and 500 miles north and south (map, fig. 1). Among the cities known to be infested are Houston, Tex., Shreveport, La.,

¹ Newell, Wilmon, and Barber, T. C. The Argentine Ant. U. S. Dept. Agr. Bur. Ent. Bul. 122, p. 14. 1913.

Texarkana, Ark., Nashville, Tenn., Memphis, Tenn., Augusta, Ga., Atlanta, Ga., Charleston, S. C., and Wilmington, N. C.

DISPERSION.

Under natural conditions the Argentine ant spreads very slowly, and this spread is controlled to a large degree by the available food supply. Like most other species of ants, the Argentine ant is a very industrious forager, and a shortage of food tends to hasten its dispersion. In October, 1914, a small infestation covering the most of two city blocks was found in Memphis, Tenn. The ant numbers could not have increased to any appreciable extent during the rather long and cold winter of 1914-15, and yet in the early part of the following June the infestation was found to involve nearly the whole of five blocks. In October, 1915, it developed that the boundaries had not been extended, though the ant numbers had greatly increased. The food supply must have increased as fast as did the numbers of ants.

In several instances frequent observations made at points on the frontier of the infestation developed the fact that the normal advance will average from 300 to 400 feet a year. The abundance of native ants has some influence on this advance, since the Argentine ant will not tolerate any of the native species, and in consequence a continuous fight is waged all along the frontier.

Heavy, flooding rains are undoubtedly a factor in the natural distribution of this ant, and in the vast region drained by the Mississippi River and its tributaries it will be remembered that there are at least two dangerous flood seasons and sometimes more, which contribute to and accelerate the distribution of this species. Lumber, rotting trees, uprooted shrubs, cane growth, fruit, vegetables, and all manner of refuse contribute to the mass of matter borne on the crest of flood water, and in this the ants seek refuge and are involuntarily transported. Nature has endowed this species with a remarkable habit of self-preservation from drowning in times of floods, for when rising water floods their nests and no other means of escape are presented they cluster together and form a compact ball. The immature stages form the center of this ball, with the queens and workers as the outer portion. As the ball enlarges from the addition of other workers which had been struggling alone in the water it gradually revolves. It is kept revolving slowly by the outside workers continually striving to reach the top of the ball, thus permitting air to reach the interior. The writer has had only one opportunity of witnessing the formation of a ball of this kind. After a 5-inch rainfall several balls, none more than 2 inches in diameter, were observed. According to reliable authorities, such balls have been observed on many occasions, some of them from 6 to 8 inches in diameter. The ants in

these balls disperse when they come into contact with a secure resting place, such as a floating piece of timber or land, but they have been seen to float around for hours on still water. Mr. Smith, at Daisy, La., states that he destroyed a large number of these balls by pouring some coal oil on the water. The balls quickly broke up when in contact with the oil and the ants died in a very short time.

Driftwood is another important carrier of this pest. A fallen decayed log is an ideal nesting place. Such a log will usually decay from the underside upward, the upperside or top making a roof for the nest, with the rotted wood below drawing and retaining ample moisture, thus affording excellent material in which to make galleries. Logs of this kind are light and easily floated and are important factors in spreading infestations. Especially is this the case in those parts of the country where heavy, flooding rains occur. In this manner practically all the land along the Mississippi River below New Orleans has been infested.

However, it is to the vehicles of man that the greatest distribution must be credited. The most important are steamboats and railroads. Commodities are carried from infested territory to uninfested places and ant colonies are often to be found in shipping boxes, feeding on sugar and other grocery supplies. Practically every one of nearly a hundred steamboats landing between New Orleans and Baton Rouge is infested with the Argentine ant. Further, it seems likely that this ant was carried by boat from Charleston, S. C., to Wilmington, N. C., as the ant is to be found around the wharves and shipping in both places. So gross is the infestation in both these cities that it is possible that the species may have been introduced into Charleston many years ago on coffee ships, as it is supposed to have been introduced into New Orleans, the slightly colder winters holding it more in check.

When inspecting cities far removed from New Orleans it has been found that in the great majority of instances the infestations start immediately around the wholesale-grocery and commission-merchant establishments. This indicates that when carried long distances the ants are more likely to be taken through in solid carload lots of merchandise which are rushed to their destination than in smaller consignments. This is especially the case with perishable goods such as fruit and vegetables. Cars containing broken shipments are sidetracked at the first town to which goods are consigned, and the ants present are likely to leave the car at the first or second stop, which fact is verified in that nearly all the small towns for a distance of 150 miles from New Orleans are infested. A serious feature of the infestation of inland cities such as Texarkana, Memphis, Atlanta, and others, is that the ants, having become established in the wholesale district, are readily distributed to surrounding smaller towns

which are tributary to these centers. A point where such a distribution has occurred is Summerville, a little town 24 miles north of Charleston, S. C., which has become infested, presumably, from the latter place.

In a complete colony in the spring of the year three distinct forms of adults are to be found—queens, males (drones), and workers, the workers greatly outnumbering both the queens and the males. The workers, foragers of the colony, are imperfect females with no reproductive functions. The queens, which are the reproducing females, remain within the nest nearly all the time, and are fed and tended by the workers. The males have apparently but one function—that of fertilizing the queens. It will be readily understood that, as in the social economy of ant communities of other species, it is absolutely necessary that a fertilized queen be taken along with a number of workers before a new colony can be started. It is quite possible that almost every town and city in the Southern States has had a number of workers introduced at one time or another, but owing to the absence of a queen a noticeable infestation has not become established. Workers alone carried in this manner would die out. Such may be the case at Nashville, Tenn., where only a few workers have been found. Later observations will be necessary to decide this question.

ECONOMIC IMPORTANCE.

As a pest in cities the Argentine ant has no equal. Owing to its small size and unobtrusive color, it is able to invade practically every part of ordinary dwellings, stores, etc. It is almost omnivorous, eating most cooked foods and a considerable percentage of the raw foods that are to be found in the average pantry. It exhibits a marked preference for some foods, such as sugar, sirup, honey, jams, cakes, candies, pies, fruit, and meats of all kinds. The temperature of refrigerators or ice boxes seems to have no deterrent effect, and ants will readily invade them.

It is a common occurrence for Argentine ants to invade bed-chambers, and while they do not possess a sting, they can cause considerable pain with their mandibles. There have been many reports of babies being attacked by them in such numbers as to cause serious results, and several of these reports have been verified. In August, 1915, the writer located such a case in Augusta, Ga. A reputable citizen of that city, residing in a heavy infestation of the Argentine ants, gave the following account of such an attack on his 4-weeks-old baby:

We were awakened in the night by a weak cry from the baby, and when the light was turned on the baby's face was black with ants. They were in the baby's nose, ears, and mouth. We hurriedly carried the baby to the bathtub

and started to wash off the ants. It took us nearly an hour and a half to get the last ant off the baby. I feel sure that if we had not heard the cry, in a few hours the child would have perished.

With conditions made almost intolerable in badly infested places, it is not uncommon to find empty, unrentable houses. Realty values accordingly drop.

The nurseryman and truck grower are greatly molested by this pest, owing to the ant's fondness for the honeydew of aphids and scale insects. The ants take the best possible care of these honey-yielding species, and protect them from their natural enemies, frequently building mud shelters over them, and as the host plants grow, carry the young scales and aphids and place them on the young tender growth, where they may more easily sap the juices of the plants.

Newell and Barber¹ give a very graphic account of the manner in which the Argentine ant has invaded the orange orchards of Louisiana.

In corn, cotton, and sugar-cane fields the Argentine ant when present is constantly attending the aphids and mealy bugs, increasing the numbers of these species to an alarming degree, much to the detriment of the plants. The writer has determined that a considerable loss of sugar results from the attendance of the Argentine ant on the sugar-cane mealy bug.

HABITS.

Argentine ants are extremely social among their own kind, the individuals never having been observed to quarrel with one another, nor one colony with another. Workers may be carried for miles and placed with others of their kind and no apparent demonstrations of like or dislike are exhibited. The newcomers appear to enter into the colony spirit and are soon lost to the view of an observer. Any small nest will contain several queens which live together amicably.

The summer nest may be located anywhere—under sidewalks, under the sills of houses, in brick piles, stone piles, under a piece of board or a piece of tin, in an old tin can—in fact, in any place convenient to the food supply. In the winter months there is a tendency to concentrate into larger colonies, and they seek warm, dry, secure nesting places in which to hibernate. These desirable places are not plentiful, and where one is located the ants from some distance will seek its shelter. The winter is the most hazardous period of the year, for should a nest by any chance be flooded during a cold spell, when the ants are dormant, the chances of survival of the colony would be extremely slight. Usually throughout the latter part of December,

¹ Op. cit., p. 24.

January, and February (at New Orleans) these large colonies are found. They sometimes reach very extensive proportions and may contain several hundred queens and countless workers and immature stages. These colonies are usually located at the base of large trees on high, well-drained spots of ground, in manure piles, or in any other piles of decomposing rubbish where heat is generated. A warm day will make them particularly active, and they will form trails in all directions from these winter nests to food supplies. They may be observed traversing the trunks of trees every warm winter day, and from the trees trails are made to nearby houses, where they cause considerable annoyance.

With the advent of warm spring weather the breaking up of the large colonies occurs. This is the time of the year that food is very scarce, and at this season the ants are particularly aggressive and troublesome in the houses. *This is the best time to use poisoned sirup, which will be described later, for controlling this pest.*

LIFE HISTORY.

There are three adult forms to be found within a complete nest in the spring months of the year—the queen, the male, and the worker. A colony may be complete, however, with a queen and workers. Three immature forms are also present—the egg, larva, and pupa.

EGG.

In an artificial formicary a fertilized queen lays from 3 to 30 eggs per day when ample food is supplied. It is very probable that under natural conditions the egg production is considerably more. Only a few seconds are occupied for the laying of each egg. A worker, apparently awaiting the arrival of the egg, picks it up and transfers it to a pile of eggs already in the nest. The surface of the egg is somewhat mucilaginous and readily sticks to other eggs. This permits the workers to handle the eggs en masse and also permits of their being deposited in desirable locations on the walls and ceilings of the galleries.

The egg when first laid is about 0.3 mm. long and 0.2 mm. wide. It is elliptical, pearly white, lustrous, and without markings. As the time for hatching approaches the luster disappears. It is extremely difficult to detect the exact time of hatching. The average summer incubation period is about 15 days, but this, of course, is subject to the variations of temperature and humidity during this period.

LARVA.

The larva, when first hatched, is creamy white. Its body is very curved, but it gradually straightens as the larval growth continues. It is entirely helpless and is practically motionless.

The workers feed and cleanse the larvæ, moving them about with the fluctuations of temperature and humidity to the most desirable places within the nest. The full-grown worker larva is about 1.5 mm. long by 0.65 mm. wide. The average larval period throughout the summer months under normal conditions is about 13 days.

PUPA.

When the pupal stage is reached the sex of the individual is readily distinguishable. The pupa is white, with the exception of two distinct black eyespots on the sides of the head. The worker pupa is about 2 mm. long, the head and thorax being the larger part of it. The male pupa is about 50 per cent larger than the worker pupa, and the queen is still larger. The two latter forms may be readily distinguished from the worker pupa. The male pupa has a very large thorax and a small, closely coupled abdomen, while the queen pupa is much more symmetrical, the thorax is not so large, and the abdomen much larger than that of the male. The pedicel between the thorax and abdomen of the queen pupa is more constricted and elongated than in the male pupa.

After the first few days the color of the pupa gradually changes to creamy yellow and continues to darken until a light-brown color is reached just previous to emergence.

The duration of the pupal stage of the worker throughout the summer months averages about 13 days, while that of the male is about 22 days. No records have been established of the duration of the pupal period of the queen.

The pupæ of all the stages are aided in transformation by the workers. Upon first emerging the adult is of a light-brown color which gradually grows darker until the second day, when it becomes indistinguishable from other adults.

DEVELOPMENTAL PERIOD.

By compounding the average periods of development of the egg, larva, and pupa, a general average of 40 days results, which represents the complete development from egg to adult in the case of the worker and a somewhat longer period for the males and queens.

ADULT FORMS.

The worker is about 2.5 mm. in length and of a dark-brown color, and there is only one caste. The workers forage for food, attend the queen and the young, and fight to protect the colony. A large percentage of the workers stay within the nest at all times and are always ready for any emergency, whether it be to fight invaders or to hurriedly seize the immature stages and retreat to securer locations upon the slightest indications of rain or flood.

The workers are able to carry considerable liquid food in their abdomens, which become distended and transparent. This food is regurgitated when the nest is reached, and fed to the immature forms and other workers and queens in the nest. They are quite long lived and have been kept in artificial formicaries for many months at a time. It is quite possible that they may live a year under natural conditions.

The male is always winged. It is readily distinguished by its massive thorax, small head, and abdomen. It is about 3 mm. in length, and the body color is of a dark brown, the same shade as the worker. Males appear in the nest in the spring months of the year and gradually lessen in numbers as the summer advances.

When the queen first emerges she is winged, but at the time of copulation, or about that time, she loses her wings, and her activities from that time are devoted to egg producing. The deälated queen is about 6 mm. long and of the same color as males and workers. It is seldom that the queens leave the nest unless disturbed, but occasionally they may be seen crawling along an ant trail in company with the workers. At rare intervals they travel alone and may be observed wandering about aimlessly.

The queens have frequently been kept within artificial formicaries for more than a year, and it is reasonable to suppose that they will live much longer.

NATURAL CONTROL.

It would appear that heavy rains and resulting flood are the only factors of natural control of any great importance. They are especially effective if occurring during cold weather, for at this time the ants are sluggish and unable to exert themselves. Moderately cold weather does not appear to check their activities.

On November 18, 1911, a heavy infestation of this ant was discovered at Kosciusko, Miss., about half the town being infested. Residents stated that they had been troubled for about 7 years; several of them, owing to the great annoyance, had moved to parts of the town which were not then infested. On revisiting Kosciusko in April, 1912, the infestation had decreased to such an extent that it was quite difficult to find any of the ants. The meteorological records of the winter months revealed the following striking facts: The mean average temperature of the 6 months from November to April, inclusive, was 49.5° , but the rainfall for this period was excessive, reaching the total of 41.1 inches, whereas the average 10 years' precipitation for these months had been only 27 inches. This control was, however, only temporary. In June, 1915, Kosciusko was again visited and the ants were found to be very numerous and causing great annoyance to residents. The infestation had spread

over practically the whole town, as well as near-by corn and cotton fields.

During the same winter (1911-12) similar conditions were experienced at New Orleans, the winter months being accompanied by a rainfall of 41.56 inches, as compared to the 10-year average of but 26.1 inches. The numbers of ants were greatly reduced, the mortality probably being at least 70 per cent. The ability of this species to overcome such a catastrophe was well illustrated, for by September, 1912, the ants had apparently reached their maximum numbers.

REPRESSION.

OUTDOOR BARRIERS.

A number of experiments have been conducted to discover, if possible, an efficient outdoor barrier.

The sticky substance which is used in coating flypaper and is also sold in bulk for banding trees was effective for only a few days. The ants would carry particles of dirt and build a bridge over it. This substance, made much thinner than usual, as suggested by Mr. D. M. Rogers for use in the gipsy-moth work, was tried and with more successful results. Heavy bands 4 inches wide spread on two magnolia trees were effective for two months in the summer without having to be replenished or combed.¹

In the cooler parts of the year these bands require frequent attention on account of the growth of mold on the surface. During wet weather in the winter in Louisiana this mold will form in a very few days, and the efficiency of the sticky band will be entirely destroyed.

It was found that 5 per cent of a carbolized oil added to the thinner preparation increased the effectiveness of the bands considerably and entirely prevented the growth of mold. The bands were also rendered more repellent and more resistant to winter conditions. A thin crust forms over the surface of the bands in the winter, but this is readily combed into the band in the spring and the band is as effective as ever. The crust on bands of the thinner preparation without the carbolized oil becomes too hard during the winter, and it is necessary to use fresh material in the spring. These bands were used on fig, magnolia, pecan, and orange trees and no injury to the trees was apparent. There is a possibility that the substance may be harmful to trees with a more tender bark, however.

To the thinner preparation were added in different tests 1 per cent of bichlorid of mercury, 2 per cent of nicotine sulphate, 10 per

¹ A wooden comb is supplied by the manufacturers for the purpose of combing the bands when a coating of dirt, insects, or any other foreign matter collects on the band. This foreign material is mixed in with a clean sticky substance, immediately under the surface of the band, and the band is as efficient as ever.

cent of naphthalene, and several other repellents. While bands containing bichlorid of mercury and nicotine sulphate were effective for slightly longer periods than the sticky substance alone, their use is hardly to be recommended.

INDOOR BARRIERS.

Perhaps the most effective and durable barrier which can be used indoors is a bichlorid-of-mercury tape or band. Tape is soaked in a saturated solution of bichlorid of mercury and then hung up to dry. It is then placed around the legs of tables, safes, etc., and if it is kept dry will last from six months to a year. Common lampwick one-half an inch wide is ideal for this purpose. After it has been treated in a saturated solution of bichlorid of mercury and dried, pieces are wrapped around the leg of the piece of furniture to be isolated and ends lapped over tightly and pinned. The tape can be readily renewed by another soaking in bichlorid of mercury and repinned in place.

Twenty-five per cent of bichlorid of mercury mixed in shellac may be painted around the legs of furniture, and when dry it will be quite as satisfactory as the tape.

Extreme caution is advised in handling bichlorid of mercury, as there is always an element of danger in using this poison. In recent years the sale of this drug to the layman has been practically discontinued.

A simple and efficient, though perhaps unsightly, barrier may be made by placing the legs of furniture in saucers and putting a generous supply of moth balls in each saucer. The moth balls will slowly volatilize, and it is necessary to add more from time to time, but the ants will not cross the barrier thus formed.

Coal oil placed in saucers in which the legs of furniture rest will repel the ant, but the odor of the oil is disagreeable to most persons.

ANT POISONS.

Many and varied experiments have proved that it is futile to try to exterminate Argentine ants with a poison which kills rapidly. A few workers may be killed, but the masses of ants will quickly recognize the source of fatality and avoid the "doctored" food. The few workers killed in this way will have no effect in reducing the numbers. None of this poison will reach the queens in the nest, and it has been found that it is essential to kill off the queens in order to prevent further multiplication of the pest.

Soon after the writer took up the work on the Argentine ant Mr. L. J. Nickels¹ published an article on the control of the Argentine ant in California, in which a rather successful poisoned sirup was described. It was decided to give this poisoned sirup a thorough trial

¹ Nickels, L. J. Field Work in the Control of the Argentine Ant. Jour. Econ. Ent., v. 4, no. 4, pp. 353-358. 1911.

in the Southern States. The following experiment is based on Mr. Nickels's recommendations:

EXPERIMENT AT HATTIESBURG, MISS.

At Hattiesburg, Miss., an infestation of 8 blocks was found to be an ideal place for this experiment.

The following buildings were located within the infestation: Thirty-eight residences, 7 stores, 2 meat markets, 2 small hotels, 2 restaurants, 2 bottling establishments (which will be designated hereafter as establishment A and establishment B), a laundry, a marble factory, a sawmill and office, and a church.

Thirty dozen 1-pint fruit jars were prepared in the manner outlined by Mr. Nickels. The porcelain was broken out of the metal tops and five holes about three-eighths inch in diameter were punched near the center of each top. Sponges were cut up into pieces and a piece inserted in each jar. The piece of sponge filled about a third of the space in the jar.

A gill of the poisoned sirup was put into each jar. On each jar was pasted a poison label.

On September 28, 25 dozen of these jars were distributed—about six jars placed in each house and store. Two vacant blocks were not covered at this time, but on November 16, 3 dozen jars were distributed on these blocks. As the jars had to be placed outdoors, they were laid on one side to prevent rain from entering. The residents of the other blocks were questioned as to results, and they reported very favorably. In most cases the ants had become much less abundant. The two meat markets had fewer ants than before, but the sirup rooms of both bottling establishments were as badly infested as ever, the ants evidently preferring the flavored sirups to the poisoned sirup.

In the latter part of April, 1912, the infestation was again determined. This was immediately after the winter previously referred to, when the infestation had been so reduced at Kosciusko and New Orleans. Though the numbers of ants had certainly been reduced in Hattiesburg, they were still present in proportionately greater numbers than in New Orleans. It is likely that the better wintering facilities at Hattiesburg were due particularly to excellent drainage and the presence of numerous trees.

On June 18 another inspection was made. The numbers of ants were at this time about 60 per cent of what they were during the previous November. The eastern line of infestation had not been extended and the ants were giving little trouble in the houses, though they had apparently concentrated around the sirup rooms of both bottling establishments. The stores and meat markets had not been troubled to any extent, but there were many trails of ants on the trees. Many of the jars were examined, and it was found that a de-

composition had taken place in the sirup in the jars, a very disagreeable odor being given off. As many of the jars as could be found were collected. These were thoroughly cleaned, especially the sponges, which were washed in boiling water. Fresh sirup was prepared and the jars recharged and again distributed.

The jars were again recharged in October. At this time, though the infestation had not spread, the ants were more numerous. They were very numerous in the sirup rooms of both bottling establishments, and in both meat markets.

Observations were made in December, and at this time conditions were fairly satisfactory. Ants had troubled only two of the houses, in each instance only for a day or so, and had then left. The bottling establishments were closed for the winter. The intention was to recharge the jars at this time, but the status was so satisfactory that it was decided to leave them until the following spring.

In the beginning of April the ants were not very plentiful. Only three houses had been invaded during the winter. The sirup rooms of both bottling works were again besieged.

By the latter part of May the ants were more numerous all over the infested area, though none of the residents or storekeepers had so far been troubled. The proprietor of bottling establishment A now had his sirups isolated and the ants were noticeably fewer around this building, but they were in increased numbers around the other plant. The ants were now very numerous on one block, and as the jars had not been satisfactory outdoors, special paraffin-covered rainproof paper bags were prepared to place on the trees near the houses and along the streets throughout the infested area. The experiment had been conducted for 20 months and the results had not been entirely satisfactory. The ants had been almost completely kept out of the houses and stores, except the sirup rooms of the bottling works, but large numbers were still present outdoors.

It is fairly conclusive that the sirup within the houses repelled the ants, for even in the spring the ants gave little trouble to the residents.

On July 9, 50 paper bags¹ containing this sirup were placed on trees throughout the infested area. About half of these bags were placed on trees in one block. All the bags were tacked about 15 feet above the ground to keep them out of reach of children and to arrest evaporation as much as possible, bags at this height being in the shade.

On August 13 a status inspection was made, and very remarkable results were observed. There were not at this time more than 20 per cent of the ants on the trees as compared with July, and all of the houses without exception situated anywhere near the trees had

¹A description of the preparation of this bag is given on pages 20 and 21.

been invaded. None of the stores along Bay Street, near which were no trees, had been bothered by the ants. All the jars were recharged.

In November conditions were very satisfactory. Comparatively few ants were to be seen, and these were mostly on the trees. No ants were to be found in the sirup room of bottling establishment A, and there were very few in the vicinity of the building. There were very few ants on the trees in one block. By far the largest number of ants were to be found around the building in which bottling establishment B had been located. People in the house next to this building were being considerably troubled.

In January, 1914, all the jars were recharged and 150 paper bags containing the poisoned sirup were distributed over the infested area.

On April 7 a thorough inspection was made, and the numbers of ants were found to be greatly reduced. Nowhere had the ants caused any annoyance. There were very few ants on any of the trees. In several places native ants had again taken up their abode within the infested area, indicating that the Argentine species was dying out.

In the latter part of May the jars were recharged and 300 poison bags placed in suitable locations. An inspection at that date proved that the experiment was continuing very satisfactorily.

Native ant nests could be found dotted over the whole area. The largest number of Argentine ants was found around the abandoned building of bottling establishment B; in fact, this was the only place where the ant could be found in large numbers.

An inspection on June 29 indicated that the experiment was progressing favorably. The numbers of Argentine ants around bottling establishment B had greatly decreased, it being actually difficult to find them on these premises. Not a vestige of the infestation could be found on three of the blocks.

In mid-September the territory was again inspected. The conditions were found to be excellent. Scarcely an Argentine ant could be seen in any part of the once-infested territory.

Everyone living in the formerly infested area was of the opinion that the Argentine ants had been completely eradicated, but the writer found a few workers. However, he decided to consider the experiment concluded, for the time at least. It was possible that the queens were all destroyed and that just a few workers remained. There was also the possibility of the native ants finally exterminating the Argentine species.

The poisoned sirup had finally proved efficient, though it must be stated that it was necessary to expose it both indoors and out.

IMPROVEMENT OF THE NICKELS SIRUP.

In the tests with the Nickels sirup a number of objectionable features were encountered which finally led to the preparation of a

greatly modified sirup. In all the experiments the sirup proved very attractive and palatable to the ants at first, but their visits gradually decreased until the sirup was avoided, although in some instances the trails continued to pass by the poison jars. The period of attendance at the sirup varied somewhat with the seasons, being longer in winter. Even in the winter, however, a repellent action was apparent. In preparing the solution it had been noticed that the sirup turned brown, becoming darker the longer it was boiled, although it was made in a pail which in turn was placed in a bath to prevent burning.

Another objection was the crystallization of the sirup to a greater or less extent upon cooling. On the advice of a sugar chemist the proportion of water was increased to make a saturated sugar solution; 10 pounds of water to 20 pounds of sugar and 1 ounce of sodium arsenite were used. The Nickels sirup contained one-fourth per cent arsenic, while this more dilute sirup contained one-fifth per cent, but the dilute sirup was quite effective. With the exception of the first application, the dilute sirup was used throughout the length of the Hattiesburg experiment. Crystallization of from 5 to 15 per cent of the weight of sirup still occurred in short periods, but as high as 50 per cent when the sirup had been in the jars for several months. This of course had the effect of proportionally increasing the percentage of poison in the liquid and consequently its repellent power. Newly made sirup appeared to be less repellent than that which had stood for several weeks.

The repellent action of the sirup is illustrated by an experiment conducted in a private residence, which was badly overrun with ants. The ants were abundant in the refrigerator, safe, and sink, and literally covered the floors. Six fruit jars containing the Nickels sirup and sponges were placed in different rooms in the house, and 6 paraffined paper bags containing the same sirup and a sponge were placed around the house outdoors on trees, fence, and back porch. The sirup was about a month old. The experiment was begun at 1 p. m. At 5 p. m. hardly an ant was to be seen in the house, although a few were to be found at each jar and many were visiting the bags. Two days later not an ant could be found in the house and only three of the bags were attended by ants. As it seemed impossible that the colonies could have been exterminated so quickly, the adjacent vacant lot was inspected. This lot was overgrown with weeds, and in a corner near the house there was a pile of old lumber. Ants were found in abundance nesting in the lumber, and many were present wherever they could find dry quarters in the lot. It was quite evident that the ants had been repelled by the poison.

A series of experiments to obtain definite data on the repellent properties of the sirup were conducted in the Horticultural Hall,

Audubon Park, New Orleans, with the Nickels sirup in the strength as recommended originally, and also double, half, and quarter strengths. One gill of sirup was used to a jar, each jar being placed on its side to give free access to the ants, to prevent the entrance of water, and to prevent mold. The "Hall" furnished ideal conditions for the experiment, the temperature throughout the year being kept high and uniform. The abundance of various species of scale insects and aphids attracted the ants in great numbers at all seasons, but especially in cold and wet weather. Three jars of each strength were used and observations were made frequently for a period of 32 days. At the time of this experiment the ants were very numerous, due to the extremely wet summer of 1912. The rate of attendance and relative repellent value of the four strengths of the poison are shown graphically in the first part of Table I.

TABLE I.—*Experiments with sodium arsenite (NaAsO_2) added (in four strengths¹) to sugar sirup solution, 1912.*

[Symbols: A=Heavily visited by ants. B=Only attended by a few ants. C=Not attended by ants.]

FIRST TEST, IN HORTICULTURAL HALL.

Date.	Double strength.			Nickels solution.			Half strength.			Quarter strength		
June 8.....	A	A	A	A	A	A	A	A	A	A	A	A
June 10.....	A	B	B	A	A	A	A	A	A	A	A	A
June 12.....	B	B	B	A	A	A	A	A	A	A	A	A
June 13.....	A	B	B	A	A	A	A	A	A	B	A	A
June 14.....	B	B	C	A	A	A	A	A	A	A	A	A
June 15.....	B	B	C	A	A	A	A	A	A	A	A	A
June 17.....	B	A	A	A	A	A	A	A	B	A	A	A
June 19.....	A	B	A	A	A	A	A	A	A	A	A	A
June 21.....	B	B	A	A	A	A	A	A	A	A	A	A
June 22.....	B	A	A	A	C	A	A	A	A	A	A	A
June 26.....	A	C	C	A	B	C	A	A	C	C	A	A
June 28.....	C	C	C	A	B	C	A	A	C	C	A	A
July 1.....	B	A	A	B	C	C	A	C	C	C	A	A
July 2.....	C	B	C	C	C	C	A	A	C	C	A	B
July 5.....	C	B	C	C	C	C	A	B	A	C	A	A
July 8.....	C	C	C	C	C	C	A	A	C	C	A	A
July 10.....	C	C	C	C	C	A	A	B	A	C	A	A

DUPLICATE EXPERIMENT, USING PAPER-BAG SIRUP CONTAINERS TACKED ON FIG TREES (OUTDOORS).

July 26.....	A	B	C	A	B	B	A	A	A	A	C	A
July 28.....	B	A	C	A	A	A	A	A	A	A	A	A
July 29.....	A	B	C	A	A	A	A	A	A	A	A	A
July 30.....	A	B	C	A	A	A	A	A	A	A	A	A
July 31.....	C	B	C	B	B	A	A	A	A	A	A	A
August 1.....	C	A	C	C	A	A	A	A	A	A	A	A
August 2.....	C	C	C	C	B	A	A	A	A	A	A	A
August 3.....	B	C	C	A	A	B	A	A	A	A	A	A
August 5.....	A	A	C	A	A	A	A	B	A	A	A	A
August 12.....	A	A	C	A	A	A	A	A	A	A	B	A
August 14.....	B	B	C	A	A	A	A	A	A	A	A	A
August 16.....	B	C	A	A	A	B	A	A	A	A	A	A
August 19.....	B	B	C	A	B	B	A	A	A	A	A	A
August 21.....	C	C	B	B	A	C	A	A	B	A	A	A
August 23.....	B	C	C	A	A	B	A	B	A	A	B	A
August 26.....	A	C	B	A	A	A	A	B	A	A	A	A
August 29.....	A	B	C	A	B	C	A	A	B	A	A	A
August 31.....	A	A	C	A	B	B	A	B	A	A	A	A

¹ Double strength.....10 pounds granulated sugar + 5 pounds H_2O + 1 ounce NaAsO_2 .
 Nickels solution.....10 pounds granulated sugar + 5 pounds H_2O + $\frac{1}{2}$ ounce NaAsO_2 .
 Half strength.....10 pounds granulated sugar + 5 pounds H_2O + $\frac{1}{4}$ ounce NaAsO_2 .
 Quarter strength.....10 pounds granulated sugar + 5 pounds H_2O + $\frac{1}{8}$ ounce NaAsO_2 .

The experiment was duplicated, except that the sirups were placed in waxed paper bags tacked on fig trees. These bags each held a gill of sirup, and sponges were placed in the sirup to allow easy access of the ants. At the time of conducting the experiment the figs were ripening and the ants were visiting the trees in immense numbers. It will be seen from the second part of Table I that the results were substantially the same as in the indoor experiments. The two experiments may be summarized as follows:

The most concentrated sirup (2 ounces sodium arsenite) attracted great numbers of ants in only 32 counts, few ants in 34 counts, and no ants whatever in 39 counts.

The standard Nickels sirup (1 ounce sodium arsenite) attracted great numbers in 62 counts, few ants in 25 counts, and no ants in 18 counts.

The half-strength solution ($\frac{1}{2}$ ounce sodium arsenite) attracted great numbers in 88 counts, few ants in 12 counts, and no ants in 5 counts.

The quarter-strength solution ($\frac{1}{4}$ ounce sodium arsenite) attracted great numbers in 92 counts, few ants in 4 counts, and no ants in 9 counts.

The experiments prove, therefore, that the excessive quantities of the arsenic in a sirup will cause it to become repellent. The observations also indicate that the sirup decomposed more rapidly as the amount of the sodium arsenite increased.

Dr. W. E. Cross, research chemist of the sugar experiment station at Audubon Park, was consulted with regard to the various defects in the Nickels sirup. His explanations and suggestions, which were of great importance in the further conduct of the investigations, are given below.

When granulated sugar (or sucrose) is heated, it is partially changed to invert sugar (or glucose), and if to this is added sodium arsenite, which has an alkaline reaction, chemical decomposition takes place. When heated this reaction is hastened and the compound becomes darker and darker. On account of the instability of the sirup, it will further decompose on standing and the final product will be a substance with an unpleasant odor and taste. The addition of a small quantity of tartaric acid to the sugar sirup before adding the sodium arsenite will produce a greater inversion of the sucrose, thus lessening the danger of crystallization, and will neutralize the alkalinity of the sodium arsenite, preventing decomposition. If a slight acid reaction is obtained the sirup will keep indefinitely. The inversion of the sucrose reduces the sweetness of the sirup, and to balance this 7 per cent of pure honey is added.

The preparation finally proposed by Dr. Cross is made as follows:

Prepare a sirup:

Granulated sugar-----	pounds--	15
Water-----	pints--	7
Tartaric acid (crystallized) ¹ -----	ounce--	$\frac{1}{4}$
Boil for 30 minutes. Allow to cool.		
Dissolve sodium arsenite (C. P.)-----	ounce--	$\frac{1}{4}$
In hot water-----	pint--	1
Cool. ² Add poison solution to sirup and stir well. Add to the poisoned sirup:		
Honey-----	pounds--	1 $\frac{1}{2}$
Mix thoroughly.		

On April 23, 1914, Dr. Cross and the writer prepared two sirups of the above formula (exclusive of the honey, which only makes the sirup more palatable), except that one lacked the tartaric acid. After cooling, they were tested in a refractometer, with the following results:

Sirup with tartaric acid, specific gravity 1.339, Brix (sugar content) 68.8.

Sirup without tartaric acid (Nickels sirup), specific gravity 1.343, Brix 68.95.

The Nickels sirup had lost 0.75 per cent of its sugar content and was of a very dark brown color. The new sirup was bright yellow (amber color), clear, and transparent. Equal samples of each were placed in quart exhibit jars with ground-glass stoppers, labeled, and set aside. A second reading was made on June 20, 1914, as follows:

Sirup with tartaric acid, specific gravity 1.340, Brix 68.40.

Nickels sirup, specific gravity 1.3321, Brix 67.01.

The new sirup had lost 0.4 per cent of its total solids and had not noticeably changed in color or sweetness. The Nickels sirup had lost 1.04 per cent of its total solids, was nearly black, partly crystallized, and had lost much of its sweetness. In the beginning of August the stoppers were removed and cheesecloth tied over the mouths of both jars, to find how evaporation would affect these sirups. The jars were placed on a shelf in the laboratory. In the beginning of January, five months after the jars were first left open, they were examined. Figure 2 shows the conditions. The difference in the quantity of the sirups, in color, and in the crystallization that had taken place within the jar containing the Nickels sirup may readily be noted. A reading was taken of these sirups, as follows:

Sirup with tartaric acid, specific gravity 1.385, Brix 75.48.

Nickels sirup, 1.367, Brix 72.68.

¹ In the first experiments one-half ounce of tartaric acid was used, but this is found unnecessary.

² In earlier experiments the sirup was boiled 30 minutes after addition of the poison, but boiling will raise the "Brix" (total solids), which is to the disadvantage of the sirup as an ant bait.

The Nickels sirup¹ was then drained from its jar and was found to weigh 160 grams. The jar and crystals were then weighed, the crystals dissolved out of the jar, and the weight of the jar subtracted from the total weight of the jar and crystals. It was found that 333 grams of sugar crystals were present.

	Grams.
Weight of sirup when first made.....	660.23
Weight of sirup remaining + sugar crystals.....	493.00
Water passed off by evaporation.....	167.23

The 660.23 grams of sirup contained 1.333 grams of sodium arsenite with a poison content of 0.202 per cent.

The 160 grams of sirup remaining contained 1.333 grams of sodium arsenite. The poison content was now 0.836 per cent.

The sirup with tartaric acid had a small precipitation. As the Brix had been raised 7.4 per cent through evaporation, the poison content was very slightly raised. This sirup now weighed 643.35 grams, the color and sweetness being still quite stable.

Immediately after preparing these two sirups, April 23, 1914, 2 fruit jars of each, containing 1½ gills of sirup apiece (without honey), were set out along heavy ant trails in the Horticultural Hall. Absolutely clean and odorless sponges were used.

For the first 4 days the ants showed a preference for the old type of sirup (without the tartaric acid) but for the next 21 days they showed no preference. Then one jar of the old sirup was abandoned.

This proved to be partially decomposed. On moving to another spot it was attended for 10 days more, then abandoned completely. Thus for a total of 35 days this jar attracted the ants. Seven days later the other jar of this sirup was abandoned and no matter where placed neither jar had any attraction for the ants.

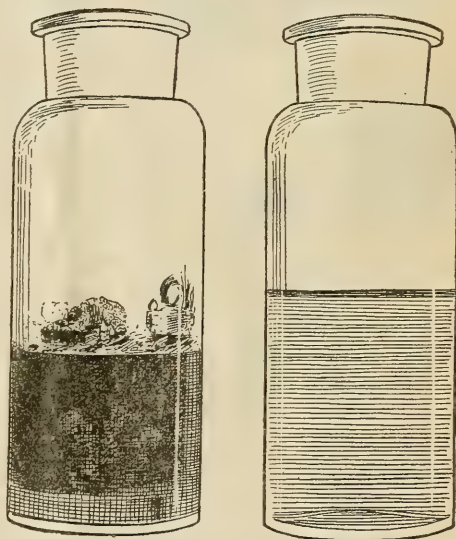


FIG. 2.—Comparison of the improved sirup (right) with the Nickels sirup (left), showing the amount of sirup left in each and the amount of sugar in the Nickels sirup. (Original.)

¹ Figure 3 shows the small quantity of sirup that still remained, as well as the large bulk of sugar crystals which had formed in the jar. The jar containing the acidified sirup is placed at the side for comparison.

The jars with the new type of sirup were visited constantly for 62 days, or to the conclusion of the experiment. The small amount of sirup left was still clean and as sweet as at first.

Tests of the poisonous qualities of both liquids were made with colonies in Janet cages, under control as to food. There was practically no difference in toxicity. Workers in both cages began to die in 4 days, the queens stopped ovipositing in 14 days, and winged males died very quickly, the queens in 17 days, and the whole colony in each case was exterminated on the thirty-second day.

PRACTICAL TESTS OF THE IMPROVED SIRUP.

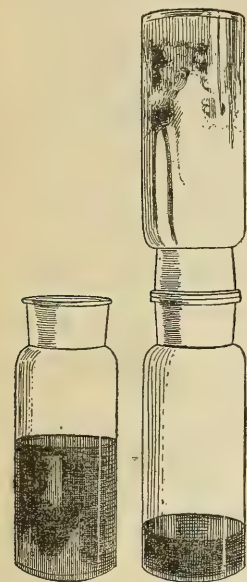


FIG. 3.—Comparison of the improved sirup (left) with the Nickels sirup (right) after five months' evaporation. The improved sirup is still clear and sweet, while the Nickels sirup is dark and full of crystals and decayed matter. (Original.)

The new sirup, made exactly as in the formula given above, is very palatable to the ants at any season of the year. It was found that containers charged with it placed at selected points outside a residence would attract the ants and they would cease to invade the house. A private residence in a large plot of ground on a street corner with a row of large oak trees along each street was heavily infested with ants, which were to be found in the sink, the refrigerator, all over the floors, etc. On June 18, 6 cans each containing this sirup and a sponge were hung on the brick pillars which supported the house. The following morning there was scarcely an ant to be seen in the house and the ants were attending the sirup in large numbers. The same conditions existed throughout the length of the experiment, which

was terminated on August 10. Many such small experiments have been conducted, the results being equally successful.

APPLICATION OF THE SIRUP.

The paraffin-covered paper bag¹ shown in figure 4 is undoubtedly the cheapest container. It can be made in large quantities at a cost of about \$5 per thousand. Small 1-pound bags used in grocery stores are obtained, and two or three holes about one-fourth inch in diameter are cut through each folded bag with a leather-punch or similar instrument. This provides each bag with two holes on each side for the entrance of the ants. Being opened, the bags are dipped in a pan of molten

¹ The writer is indebted to Mr. R. W. Moreland, Bureau of Entomology, for his suggestions in the preparation of this waterproof container.

paraffin and set aside to dry. The paraffin, forming a waterproof surface, materially lengthens the life of the bag, which is protected from the entrance of water through the holes by part of another (2-pound) paraffined bag which covers the first one like a canopy. In use, each bag is provided with a small quantity of poisoned sirup and a piece of sponge, the protecting outer piece of bag is drawn up over it, and the ends of both are folded over at the top and tacked to a tree. On account of the bag coming together at the top it is very narrow at the point where the entrance holes are made; consequently very small pieces of sponge are required. The bags have been known to last for long periods, but the larger percentage of them last only about 2 or 3 months. They can not be recharged.

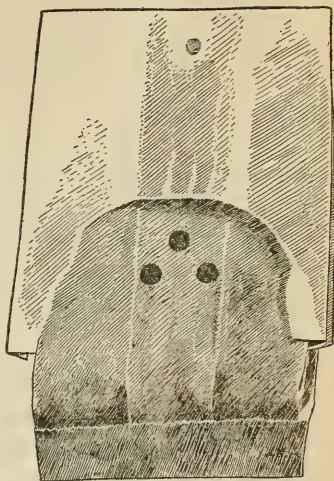


FIG. 4.—Paraffined paper bags arranged as a container for ant poison sirup. The apron has been cut away to show the ant entrance holes. Such bags are nailed to trees. (Original.)

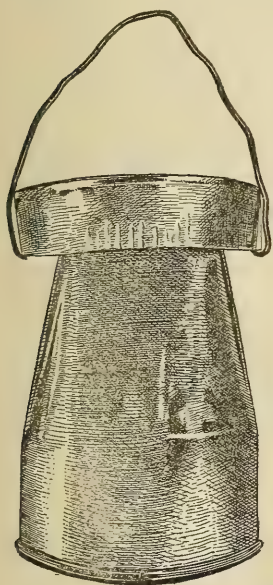


FIG. 5.—Tin can container for ant-poison sirups used in outdoor experiments. (Original.)

The tin can shown in figure 5 is the most satisfactory

container. Any sized can may be used, but the handiest size is the one-half pound baking-powder can. The can must have a friction cover, and of course it must hold water. If the can is indented deeply on the two opposite sides (as illustrated in the drawing, fig. 5) and the cover replaced, it will be observable that there is ample space between the top of the can and the cover for the entrance of the ants, and the can, if kept in an upright position, will be weatherproof. About a gill of the sirup will be sufficient for several months, but in heavy infestations it is better to put 2 gills in each can. It is very advisable to place a fairly large piece of sponge in the can. The sponge will float on the sirup and allow the ants to feed in large numbers. A piece of wire about 6 inches

long may be bent for a handle, a hook inward at each end being made. The hooks may be attached under the lid of the can where it projects over the part that has been indented. This forms a handle by which

the cans may be hung on trees, fences, walls of houses, etc. The ants prefer to climb for their food, and it is well to hang the cans near ant trails going up trees, walls, etc. It is advisable to hang the cans in the shade to prevent the evaporation of the sirup, for though it has been proved that evaporation does not affect this sirup to a marked extent, it is well to avoid raising the solid contents of the liquid. Eight to ten of these cans should be sufficient to place around an ordinary city house and lot. If the grounds are large and if many trees are present, more cans should be placed out.

From the results so far obtained, the careful preparation of the poisoned sirup can not be too highly emphasized. Very accurate balances are necessary for the weighing out of the poison and the tartaric acid. This is especially true when small quantities of the sirup are prepared.

PLANS FOR MUNICIPAL CONTROL WORK.

In effecting control in towns and cities it is first necessary to ascertain the extent of the infestation. This should be mapped out so that workmen in distributing the cans will be able to refer to the map to insure the covering of the entire territory. Cans may be obtained at wholesale at about \$16 per thousand. About 10 pounds of "grass" sponges will be required per 1,000 cans. These will cost about 75 cents per pound. The sponges should be thoroughly washed and dried before use. When wet they may easily be torn into pieces about 2 by 2 inches. Using 1 gill of sirup per can, 200 pounds of granulated sugar will be required per 1,000 cans. The cost of the sodium arsenite is about 80 cents per pound, and 1 pound will be sufficient for 1,500 cans. Tartaric acid (crystallized) costs about 70 cents a pound, which will be enough for 4,500 cans. From 60 to 100 cans will be required per block, depending on the size of the block. The late fall, winter, and spring are the most desirable times in which to do this work, as in these seasons the natural food is least plentiful and the ants most hungry. Two men should be able to prepare the sirup, wash and tear up the sponges, and charge about 2,000 cans per day and distribute about 1,000 cans per day.

TRAPPING ANTS.

By taking advantage of their winter colonizing habit the ants may be attracted in large numbers to specially prepared trap boxes, which may be fumigated when large numbers have gathered in these boxes for winter nesting. Newell and Barber, who originated this method of control, describe in Bureau of Entomology Bulletin 122 some very interesting and successful trap-box experiments. The boxes were filled with decaying vegetation, the heat generated making them very attractive as hibernating quarters. Carbon bisulphid was found to

be the best and most economical fumigant for use in the trap boxes. It is hardly necessary to state that this method of control is not applicable to city conditions, where dry nesting quarters are very plentiful and the ants do not colonize to any great extent.

SUMMARY OF CONTROL MEASURES.

ANT BARRIERS.

In grossly infested houses much relief may be secured by isolating tables, refrigerators, safes, beds, etc., with bichlorid-of-mercury tape, or by placing the legs of articles of furniture in saucers filled with moth balls or coal oil. Trees, beehive stands, and other outdoor objects may be isolated with the sticky substance used on fly paper but made thinner than usual. If 5 per cent of carbolized oil be added, the durability of the bands will be considerably increased.

REPELLENT ANT POISONS.

Repellents are much used to keep the ants from buildings. Strong antimony or arsenical sirups, a number of which are sold by druggists in infested territory, are used for this purpose. They give quick relief for short periods, but they are not a factor in the reduction of the infestation.

ATTRACTIVE ANT POISONS.

The only effective poisons yet known for permanent control are poisoned sirups. The improved arsenical sirup recommended on page 18 will not spoil and is superior to any other formula yet tested on account of its stability at high temperatures, freedom from crystallization, and continued attractiveness.

TRAPPING ANTS.

Trapping ants may be accomplished in rural locations by providing boxes of decaying vegetation in the winter. The colonies will move into these boxes and the ants may then be killed with carbon bisulphid.

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PROFESSIONAL PAPER

August 22, 1916

FISH MEAL: ITS USE AS A STOCK AND POULTRY FOOD.

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INTRODUCTION.

The use of fish meal in this country at the present time for feeding purposes is so limited that it may be said that in commercial quantities it has scarcely begun to be marketed. The Connecticut Agricultural Experiment Station¹ in its report on feeding stuffs for the year 1914 gives the results of examination of one commercial brand sold by an eastern firm. Fish meal is used by another eastern firm as the protein basis of a poultry food. It has been prepared for some time on the Pacific coast, and there are several brands already on the market from that region. One of these products is made of a mixture of fish meal and meat meal. As commercial by-products fish and the waste residue from fish have always in this country been converted into so-called "scrap" or "pomace" for use as a fertilizer ingredient. An entire industry, the fish-scrap fertilizer industry along the Atlantic coast, has grown up, in which a single species of fish, the menhaden, is used as a source of raw material. In the early days

¹ Conn. Agr. Exp. Sta. Rpt. 1914, pt. 4, p. 221.

NOTE.—The object of this publication is to set forth the value of fish meal as a food for domestic animals, in order to stimulate its more general use as a supplementary stock food and to encourage its manufacture for that purpose.

of this industry the oil was the principal material sought; the "scrap" was considered waste and was not generally used as a fertilizer.

It is indeed surprising that in the matter of furthering economy the use as a stock food of fish meal prepared from undecomposed raw material has not been fostered in this country. This is particularly striking in view of the fact that attention was called to the possibilities of fish meal as a feeding stuff a number of years ago, both in this country and abroad. In 1877 Dr. W. O. Atwater¹ reviewed the manufacture and use of fish manures and at that time urged the use of the fish scrap from the menhaden as a source of protein for stock foods. Such use of this material would have made possible the utilization of its high feeding value and at the same time would not have impaired, but to a great extent would have enhanced, its fertilizing value. The fertilizing constituents would be more available after digestion, and manure from animals so fed would contain the plant food material derived from the fish in a more readily assimilable form.

The experimental work on the use of fish meal as food for stock dates back to the time when similar work was conducted in connection with the use of meat meal and tankage for this purpose. In fact, in this country even before the attention of feeders was called to these latter foodstuffs as supplementary stock foods, reports of experiments directed attention to the use of fish as food for domestic animals. Dr. Atwater² in his report records the year 1835 as the earliest in which there appears any account of the use of fish as food for domestic animals.

As early as 1864³ fish "pomace" or "chum" (the residue left from herring or other small fish after removal of the greater part of the oil by pressing) was spoken of in high terms as furnishing a valuable feed for sheep, swine, and fowls, all of which ate it greedily. No doubt use was made of fish in this form, in isolated instances, by farmers living near the coasts who had access to this material in its fresh condition. The writer has been informed of its use in Maine in the early days of the sardine industry, when the residue from the packing of sardines after removal of part of the oil by pressing was fed to sheep with excellent results as to fattening and wool production.

Shortly after the time the earlier experimental work and feeding tests were made to ascertain the value of waste residues of animal

¹ See his special report on "Menhaden and other Fish and Their Products as Related to Agriculture" to Goode, "History of the American Menhaden," U. S. Fish Comm. Rept., 1877, pp. 194-267.

² Goode, Atwater, loc. cit., p. 258.

³ William D. Dana, in a report of the Maine Board of Agriculture. See *Agriculture of Maine*, 1864, p. 43.

origin and of fish meal for feeding purposes, it appears that preference was given to such material as meat meal and tankage, and that in after years fish meal was forgotten. It was also generally assumed that feeding domestic animals fish would result in imparting a characteristic taint to the food products from the animals. This impression was undoubtedly obtained as a result of allowing animals to eat too freely of fish wastes, particularly that which was in an advanced stage of spoilage. The present time—feeding stuffs of high protein content being so much in demand—would seem to be a fitting and proper one in which to call upon this reserve supply of protein so abundantly supplied by waste fish and by the waste of fish-canning industries.

REVIEW OF LITERATURE.

The literature on the use of fish meal for feeding purposes was found to be more extensive than casual inspection had shown. The greater part of the experimental work on this subject has been conducted in Germany, as a result of which the use of this material for feeding purposes in that country is now on a firm basis. The more important articles are cited here in chronological order and fairly full abstracts are given of some, in order that the accumulation of evidence may allay any prejudice that may exist against the use of fish meal as a foodstuff for domestic animals.

In 1869 M. L. Wilder,¹ of Pembroke, Me., a member of the board of agriculture of that State, presented his experience in the use of fish "offal" as a feed for sheep. He believed "fish offal to be not only cheaper but much superior to any other kind of provender he had ever used" for this purpose. The "offal" referred to was made from herring, which were salted the same as for smoking, cooked, and the oil pressed out. It is stated that the sheep ate of this more eagerly than of grain. Experiments similar to the above were made by other persons in later years.²

In 1875 Farrington³ conducted feeding experiments with sheep at the Maine Agricultural College, comparing the value of equal quantities of corn and of fish "pomace" made from herring. Two flocks of 5 lambs each were fed about 2 ounces per head per day, the lambs in each group being allowed all the hay they would eat. During the 16 weeks of the experiment the corn-fed flock gained 48 pounds, or 15.13 per cent, and the lot fed on fish 47½ pounds, or 15.01 per cent.

Henry, in *Feeds and Feeding*, reports statements from several authors to the effect that it has been determined that no bad influence on the milk is found when dried fish are fed in reasonable quantities to dairy cows, and that it has been found that 100 parts of linseed cake can be replaced in the ration for cows by 80 parts of herring cake. In one test milk and butter of normal quality were produced when 2.3 pounds of fat-free fish meal per day were fed with a variety of other feed. The statement is made by this authority that the better grades of fish meal should be used for feeding.

¹ Agriculture of Maine, 1869, p. 60.

² Agriculture of Maine, 1874-75, p. 1.

³ Cited by Atwater in Goode, U. S. Fish Comm. Rpt., 1877, p. 260.

In 1908 Lindsey¹ reported that in Europe a great variety of meat and fish meals had been offered for sale as stock foods as early as 1872. A review of a number of experiments with horses, cattle, sheep, and swine established the fact that these materials, when properly prepared, are excellent foods for stock and poultry, and that they are highly digestible.

Notwithstanding the favorable reports recorded on the use of fish meal it was ignored at this time, preference being given to dried blood and tankage. This was in part due, no doubt, to the fact that the industries producing these were more highly organized and their selling arrangements proportionately greater.

Turrentine² calls attention to the use of fish scraps as a feeding stuff for poultry and stock and gives extended quotations from the report by Goode, cited above. From his review of the early feeding of fish in this country he concludes that "the universally affirmative results of all the recorded experiments with fish scrap as a cattle feed leave little room for doubt as to its efficiency." He remarks further: "It is indeed surprising that its use as a feed has not been more generally introduced. * * * It would be fitting, indeed, that even a small part of the millions of pounds of combined nitrogen carried seaward annually by the rivers should be returned and after a short cycle again should be rendered suitable for man's consumption."

According to Kellner³ milch cows may be fed as high as 2 pounds per day with no objectionable taste or flavor resulting in the milk or butter. Feeding to sheep or horses is best accomplished by mixing it with other feeds. It is recommended that one-half pound per day be given.

F. Lehmann⁴ ranks fish meal next to meat meal in its content of nourishing material. Laboratory experiments showed that 98.6 per cent of the protein was digested with pepsin and pancreatic extract. It is also pointed out that fish meal, on account of the length of time required to render the nitrogen and phosphates available for plant assimilation, is not a very good fertilizer; but that it is a very good feeding stuff and when so used its fertilizing value is enhanced, since the fertilizing ingredients reappear in the manure in forms more easily used by plants.

Kühn-Cornieten⁵ conducted a practical test with six cows, comparing the yield and quality of milk and butter when the cows were fed a ration containing no fish meal with the results obtained when fish meal was substituted for dried malt husks and sunflower meal in the basal ration. From 1½ to 2½ pounds (German) fish meal were fed per head per day in the different trials. The milk produced during the experiment was analyzed. The yield of milk was fairly well maintained during the time fish meal was given, while the percentage of fat in the milk was increased. The butter did not have a fishy odor or taste and was declared to be about the same in quality as that produced on oil cakes. Since the quantity of milk was about the same, the percentage of fat higher, and the feed cheaper, it was concluded that fish meal was a valuable feeding stuff.

Fink⁶ fattened steers with a ration including fish meal at the rate of 3 pounds per head per day. A gain of 303 pounds in 90 days was made. Nothing is stated in regard to the flavor of the meat.

¹ Mass. Sta. Rpt., 1908, pt. 2, p. 149.

² "The fish-scrap fertilizer industry of the Atlantic coast"; Bul. No. 2, U. S. Department of Agriculture.

³ Die Ernährung d. landw. Nutzthiere, pp. 369-371.

⁴ Landw. Wochenbl. f. Schleswig. Holstein, 1892, No. 23; pp. 200-201.

⁵ Molkerei Zeitung, 1894, 8 (44), p. 675.

⁶ Deut. Landw. Presse, 1896, 23 (17) 1, p. 145.

Hals and Kavli¹ report analyses of fish meal made from slightly salted herring and from the waste of heavily salted herring. The composition of the former was: Water, 11.11 per cent; protein, 61.11 per cent; fat, 14.06 per cent; and ash, 11.79 per cent. Of the latter, the composition was: Water, 10.81 per cent; protein, 42.29 per cent; fat, 13.17 per cent; and ash, 23.06 per cent. Digestion experiments showed that 12.7 pounds of digestible fat and 56.3 pounds of digestible protein were obtained from 100 pounds of the meal made from whole herring, while the meal made from the waste of salted herring gave 11.9 and 42.6 pounds, respectively.

In 1903 V. Schenke,² as a part of an extensive investigation of commercial feeding stuffs conducted by the German experiment stations, made an exhaustive examination of the subject of fish meal or fish guano, looking toward its use as a stock food. In this report it is stated that up to the middle of the last century fish meal or fish guano was used only for fertilizer purposes, and that it was not until about 1860 that any work of a scientific nature was done with the idea of using such meal as a foodstuff for animals. Attention is called to the fact that the protein consists mainly of meat fibrin, albumen, and gelatinous substances, the latter in larger proportion than in the flesh of fresh fish because the fish meal is prepared without removing the fish bones. It is also stated that the fat which remains after the pressing is easily digestible. The ash consists largely of sodium, potassium, and calcium phosphates, and sodium, potassium, and magnesium chlorids. Experiments conducted and literature cited in regard to the digestibility of fish meal showed that the coefficients of digestibility of the chief constituents are high.

According to V. Schenke the first feeding tests with fish meal were made in 1873 and 1874 by Weiske³ and were reported in 1875 and 1876 by Kellner, Schrodt, and Wimmer;⁴ the test animals were sheep. The investigators concluded that the protein of fish meal was digested by herbivorous animals as well as, or better than, the protein from vegetable sources. From 77 to 83 per cent of the protein was found to have been digested. Kellner in a later experiment,⁵ found that sheep digested as much as 90 per cent of the protein, 76.4 per cent of the fat, and 15 per cent of the ash.

Reports of the work of a number of other investigators, extending from this year (1877) to 1902, are cited by V. Schenke, in which studies of the feeding of fish meal to dairy cows, oxen, hogs, sheep, and poultry are recorded. The results were universally favorable in all particulars as to economy in producing gains in weight, and as to lack of taint or odor of fish in the marketable products from these animals.

In conclusion this author states that fish meal is a valuable supplementary food for animals, when it is fed with other foods low in protein; that its most important feature is the high digestibility of the protein and fat and that, further, it imparted no objectionable flavor to milk and butter when used supplementally in rations for dairy cows.

In a feeding experiment on young pigs, comparing the growth obtained by feeding both milk and fish meal with the growth obtained by feeding milk only, Klein⁶ found that smaller quantities of milk with the addition of fish meal gave as good a gain per head as was obtained by feeding larger quantities of milk alone.

¹ Norsk. Landmandsblad, 1903, 22 (3) 38-41.

² Landw. Vers. Stat., 1903, 58, 55-64. For full report of this investigation see Die Futtermittel des Handels. P. Paray, Berlin.

³ Wochenbl. d. landw. Ver. i. Grossherzogtum Baden, 1874, p. 318.

⁴ Journ. f. Landw., 1876, p. 265.

⁵ Landw. Vers. Stat., 1877, 20, p. 423.

⁶ Deut. Landw. Presse, 1907, 34 (67), 542.

The comparative value of meat meal and fish meal as supplementary foods for swine was studied by A. Kleeman,¹ who conducted his experiments on 3 groups of 8 hogs each, using two grades of fish meal (one containing 2.10 per cent of fat and 48.90 per cent of protein; the other 4.80 per cent of fat and 51.50 per cent of protein) and a higher-grade meat meal, containing 80 per cent of protein. The ration, in addition to the high protein-bearing foods used, was composed of corn, steamed potatoes, potato chips, and potato flakes. Starch was used in addition to balance the ration composed of the fish meal low in fat. The deficiency of meat meal in phosphate of lime was made up by adding precipitated lime phosphate to this ration.

The pigs fed on meat meal were off their feed during the latter part of the experiment, while the lots fed the fish meal appeared to have sharpened appetites and ate the ration well throughout.

There was no difference in the Reichert-Meissl numbers of the fat of the hogs fed on meat meal and those fed on fish meal, but the iodine number of the fat was found to be slightly higher in the case of the hogs fed on fish meal. The quality of the meat and fat as regards taste, odor, and flavor was not affected by feeding fish meal. The author states that meat meal and fish meal are good fattening feeds for swine, and concludes, from his experiment, that, as food for hogs, meat meal and fish meal gave practically similar increases in weight, but that meat meal on account of the higher percentage of protein was from 60 to 80 per cent cheaper than fish meal.

This conclusion is based on the fact that in this experiment the fish meal cost a little more than meat meal.

Honcamp, Gschwender, and Engberding² report the results of experiments on sheep which were fed herring meal and whale-flesh meal, as supplementary feeds to clover hay. The herring meal used by them contained 58.30 per cent of crude protein, 56.28 per cent of "pure" protein, 3.98 per cent of nitrogen free extract, 13.57 per cent fat, and 23.65 per cent of ash. Digestion experiments conducted on sheep with this meal showed a utilization of 93.7 per cent of the organic substances, 87.7 per cent of the crude protein, 49.2 per cent of the nitrogen free extract, and 97.4 per cent of the fat.

It was noted in these tests that the animals digested the organic material of the ration as well as the crude fiber of the basal ration (clover hay) to better advantage during the period in which fish meal was fed than in the period in which no fish meal was given, a fact which has been observed before under conditions where high protein rations have been used.

In a report³ (on *Fish Guano and Its Use as Food*) by Consul General Robert P. Skinner, Hamburg, Germany, it is stated that this material is used with great success in Germany as a supplementary stock food. Large quantities of it are exported to the United States, but it is all utilized for fertilizer purposes. In Norway codling and herring are the chief varieties of fish from which this material is made, while in England and Scotland the waste from all varieties of fish is used.

Herring meal, when made from fresh fish, has a protein content of from 60 to 70 per cent and a fat content of from 10 to 12 per cent, but when made from salt herring, the protein content is only about 50 per cent and the fat content 7 or 8 per cent.

The English fish meal is pressed while being kept hot with steam and has a fat content of only 3.6 per cent. Hogs are said to eat this fish meal eagerly,

¹ Landw. Vers. Stat., 1910, 73 (1 & 3) 187-219.

² Landw. Vers. Stat., 1911, 75, 161-184.

³ Daily Trade and Consular Report, 1911-14, No. 103, p. 512. See also *American Fertilizer*, May 6, 1911, p. 32 H.

but it must be fed with care since an excessive quantity in the ration may affect the quality of the pork. Moderate quantities contribute to the animal's general health. The use of fish meal for feeding to swine is increasing in Germany from year to year.

In 1914 Klein¹ conducted feeding experiments on pigs older than those used in previous experiments but which were still growing, comparing skim milk with fat-free fish meal and dry fermentation residues. By substituting equivalent quantities of fish meal and of the dry residues for skim milk in the rations, the assimilation of these two food stuffs was observed as compared with skim milk. The results obtained show that fish meal and fermentation residues are well adapted as substitutes for skim milk. There was no marked difference in the character or flavor of the meat after slaughter.

E. Haselhoff,² in an article which includes the results of examination of 23 brands of fish meal found on the German market, points out that since this material has come to be quite extensively used in Germany as a feeding stuff its quality in many instances has greatly deteriorated. Fish meal prepared from strongly salted and from decomposed fish is condemned. One very reprehensible practice of adulteration has been the admixture of "cadaver" meal with the fish meal, to which serious outbreaks of disease (particularly anthrax) among stock have been traced. Such outbreaks result from the insufficient sterilization of the product prepared from animals dying of disease.

The composition of the different brands examined varied greatly. It was the opinion of the author that a fish meal deserving to be classed as a high-grade product should have a fat content of from 2 to 4 per cent, depending on the quantity to be used in the ration, and that the meal should not contain over 3 per cent of common salt. He recommends the following amounts of a high-grade meal in feeding rations:

Cattle, 2 pounds per 1,000 pounds, live weight.

Hogs, one-fourth to one-half pound per head, according to weight.

Sheep, one-fourth to one-half pound per 200 pounds, live weight.

The statement is made that the quality of the meat and lard is not injured by feeding hogs a little over one-half pound of fish meal per head per day.

In a special article³ the Board of Agriculture and Fisheries of England called attention to the manufacture of fish meal and its value and use as a stock food. After the closing of the German market for this product, which consumed practically the entire amount (over 18,000 tons), the English farmer was urged to adopt its use.

In support of the use of fish meal for feeding purposes experiments are cited where a meal containing 3.5 per cent of fat and 55 per cent of protein material was fed to pigs for four months at the rate of 1 pound per head per day without any harmful effect on the flavor of the meat. In another feeding experiment cited, cows were fed very large amounts of a herring meal containing 20 per cent of oil without the flavor of the milk being affected. In a more recent feeding experiment quoted in this article the feeding of English fish meal to pigs in the proportion of from 15 to 30 per cent of the other foods given led to a marked increase in the weight of the pigs so fed compared with those fed on a ration containing no fish meal. The substitution of fish meal for a definite proportion of the various foods in the ration gave increased profits, amounting in one series to 42 per cent and in another to 94 per cent per pig, notwithstanding that the actual cost of feeding was higher.

¹ *Milchwirtsch. Zentr.*, 1914, 43, 452, 458.

² *Fühling's Landw. Zeit.*, Feb., 1914, 63 (4) 137.

³ *Jour. Board of Agric.*, Nov., 1914, 21, 688.

The following quantities to be given daily, evidently taken in part from the German article quoted above, are suggested:

Cattle, 2 pounds per 1,000 pounds, live weight.

Pigs, $\frac{1}{4}$ to $\frac{1}{2}$ pound, according to weight.

Sheep, 1/10 to 1/5 pound per 100 pounds, live weight.

Poultry (adult fowls) not more than 10 per cent, and chickens not more than 5 per cent of the entire ration.

In an extensive article¹ on the "Utilization of fish and marine animals as sources of oil and manure," attention is drawn to the use of fish meal as a cattle food. It is stated that this product has been used with success as a supplementary food for stock. According to this notice there are various grades of meal now on the English market, which are made from the waste of herring, cod, and other fish.

It is stated² that the horned dogfish, *Squalus acanthias*, is sometimes dried and used for feeding purposes in Scotland, Ireland, Norway, and elsewhere. It is stated also that cod meal may be made by simply drying and grinding the fish, but that in the case of herring it is necessary to remove most of the oil by the usual process of cooking, pressing, and drying. It is further stated that a good fish meal for feeding purposes should contain not less than 8.2 per cent of nitrogen and not over 5 per cent of oil.

In a study comparing the relative feeding value of fish and meat meals for fattening pigs, G. Martinoli³ concluded that in fattening pigs from the earliest age fish meal proved of value in developing the skeleton and in stimulating the appetite and processes of assimilation. The animals fed on fish meal grew more rapidly than those fed on meat meal, and they were of superior quality. Neither the fish nor the meat meal imparted any particular smell or taste to the flesh of the animals.

In a bulletin from the Agricultural Experiment Station, Purdue University, A. G. Philips⁴ gives the results of four experiments, each extending for one year, in which the value of meat scrap, fish scrap, and skim milk in rations for laying pullets was compared.

The summary of the results of this work shows that the pullets in the pens fed on a ration containing meat scrap averaged 135 eggs per pullet on a food consumption of 70.29 pounds per bird, at a cost of 98.4 cents per bird. For the fish-scrap pens the average number of eggs was 128 per pullet on a consumption of 74.13 pounds of food, at a cost of 99.5 cents per bird. The pullets in the pens fed on a ration including skim milk, produced an average of 135.4 eggs on 157.61 pounds of food consumed, costing \$1.10 per bird.

It was determined that the amount of dry matter in the food required to produce one pound of eggs was 3.7 pounds in the meat-scrap pens, 4.02 pounds in the fish-scrap pens, 3.7 pounds in the skim-milk pens, and in the control pens, receiving none of the above materials, 13.53 pounds.

The average cost of producing one dozen eggs was 8.5 cents for the pullets fed on meat scrap, 9.7 cents for those fed on fish scrap, and 9.7 cents for those fed on skim milk. The profit per bird, over the cost of feed, was \$1.55 for the pullets fed meat scrap, \$1.56 for those fed fish scrap, and \$1.62 for those fed skim milk.

¹ Bulletin Imp. Ins., 1914, 12, 429, 442.

² Bulletin Imp. Ins., July-Sept., 1914, 12, No. 3.

³ Rev. Centro. Estud. Agron. y Vet., 1914, 7, No. 72, pp. 258-270; abstracts in: Internat. Inst. Agr. (Rome); Mo. Bul. Agr. Intel. and Plant Diseases, 1915, 6, No. 3, pp. 445-446, and Exp. Sta. Record 33, No. 6, p. 571.

⁴ Agricultural Experiment Station, Purdue University, Bulletin 182, 18, Nov., 1915.

"Poultry Investigations: I, The value of meat scrap, fish scrap and skim milk in rations for laying pullets."

COMPOSITION AND QUALITIES OF FISH MEAL.

In the earlier experiments in this country, which have been reviewed, the material referred to is the undried cakes as they came from the presses. Since the advent of drying this residue has been converted into the fish scrap of the fish fertilizer industry. With proper attention, however, to sanitary considerations in the processes, it may be made into fish meal for feeding purposes.

The preparation of the material in this form makes it at once a commercial proposition, so far as shipping and ready use in compounding stock food rations are concerned. The meal containing less than 10 per cent of moisture will keep a very long time without decomposition or apparent chemical change. Portions of the experimental lots of fish meals made from sardine waste have been stored for over a year now, with apparently no change taking place. The product is usually shipped in 80 or 100 pound bags and will probably receive the same classification as fish fertilizer scrap, which at present is classified as 6th class in carload lots, or as 4th in less than carload lots (official classification); western classification: L. C. L., 3d; C. L., C.; southern classification: L. C. L., not taken; C. L., at fertilizer rates.

During the season of 1913-14 the Bureau of Chemistry made an extensive study of the sardine industry on the coast of Maine. It was during these investigations that attention was drawn to the large amount of waste in the packing of the fish as sardines, particularly at times when the fish were of large size. The possibility of utilizing this material as a stock food was considered and an investigation of the preparation and yield of material for this purpose was instituted during the season of 1914.

The question of the utilization of the fish waste on the Pacific coast has been extensively investigated by J. W. Turrentine¹ of the Bureau of Soils of this department as a part of the investigation of the fertilizer resources of the United States. The report of this work, which covers all phases of the subject, contains the analyses of five samples of dried "scrap" which were prepared at as many different factories from the waste in the canning of salmon. As the analysis indicates, they were well dried products, the water content ranging from 3.91 per cent to 5.36 per cent. The protein content ranged from 47.69 per cent to 59.31 per cent. It can be seen, therefore, that a product from this source has considerable value as a high-protein material, and it is said to be of very high quality.

Attention is also directed in this report to the use of the higher-grade "scrap" or meal as a stock and poultry food.

¹ U. S. Department of Agriculture Bulletin No. 150.

The waste in the sardine industry affords excellent material for the preparation of a high-grade fish meal. As it comes from the packing table it has been steam cooked and partially dried in the process of preparing the fish for packing, and can be taken after collection from the packing tables directly to a plant equipped for pressing and drying. During the season of 1914 a quantity of fish meal was made in the course of experiments looking toward the utilization of this waste material as a stock food. A part of this waste is now utilized by converting it into "pomace" or "scrap" for use as a fertilizer. A number of experiments were made, using raw material varying in fat content and employing different methods of treatment preparatory to pressing and drying. The plant used for the experimental work was equipped with an iron cooker heated directly by steam, a rack and cloth screw press capable of yielding a pressure of 120 tons, and an ordinary type of rotary fertilizer drier. With this equipment a yield of from 27 to 33 per cent of meal was obtained from the fish residue; and from raw material containing from 12 to 17 per cent of oil, over one-half of the oil was removed by pressing. The oil obtained was bright, clear, and of very high quality. The fish meal from these excessively fat fish contained 17.51 per cent of oil. After pressing and drying raw material which contained from 8 to 9.5 per cent oil, a dried meal was obtained containing from 9 to 12 per cent of fat. The average composition of meal obtained in six different experiments was as follows:

	Per cent.
Water	7.71
Fat	15.19
Total nitrogen	9.39
Protein (N $\times$ 6.25)	58.70
Ash	15.18

This meal was stored in a barn at Eastport, Me., for a period of two or three months and was then shipped to Washington for use in feeding experiments after again being stored for about two months. The entire quantity, about 1 ton of meal comprising four of the experimental lots, was thoroughly mixed and was used for feeding experiments in cooperation with the Animal Husbandry and Dairy Divisions of the Bureau of Animal Industry of this department, using growing pigs, poultry, and dairy cows. The analysis of this meal and the composition of the fish are given on page 11.¹ It will be noted that there was a loss of 3 per cent of water during the time of storage and shipping.

¹ The analysis of the meal was made by H. W. Houghton; of the ash by J. B. Wilson, both of the Animal Physiological Chemical Laboratory of the Bureau of Chemistry. The nitrogen determinations were all made by the Nitrogen Laboratory of the same bureau.

Analysis of Meal.

	Per cent.
Water.....	4.74
Ash.....	16.68
Total nitrogen.....	9.68
Protein (Nx6.25).....	60.50
Fat.....	14.56
Crude fiber.....	0.61
Salt (NaCl).....	5.78

Analysis of Ash.

Insoluble.....	0.50
Iron and aluminum (Fe_2O_3 , Al_2O_3).....	0.97
Phosphoric acid (P_2O_5).....	35.32
Calcium (CaO).....	26.86
Salt (NaCl).....	25.83
Magnesium (MgO).....	3.13

FEEDING EXPERIMENTS.¹**DAIRY COWS.**

The results obtained by the Dairy Division of the Bureau of Animal Industry by feeding the fish meal described above to dairy cows, were sufficiently satisfactory to warrant a more extended study of its value as a dairy feed. This work is to be undertaken during the coming winter. The preliminary experiments showed that the cows fed on a ration containing fish meal gave a greater yield of milk than cows fed on a similar basal ration containing no fish meal, but containing cottonseed meal. The milk from the cows which were fed fish meal contained a lower percentage of butter fat, but the total yield of fat obtained was approximately the same for the two groups. There was some variation in the readiness with which the animals ate the ration containing the fish meal. As a rule cows which have not been highly fed on feeds for which they have a fondness, will eat a fish-meal ration readily and are eager for it. In these tests the feeding of fish meal had no detrimental effect on either the milk or butter.

POULTRY.

The feeding experiments with poultry and with growing and fattening pigs were conducted by the Animal Husbandry Division of the Bureau of Animal Industry.

In the test with poultry a pen of laying hens fed a ration containing the fish meal was compared with a pen of the same breed fed a ration which was the same, except that in it meat meal was sub-

¹ To Mr. George M. Rommel, Chief of the Animal Husbandry Division, and Mr. B. H. Rawl, Chief of the Dairy Division, of the Bureau of Animal Industry, acknowledgment is made for their cooperation and interest in the feeding experiments with the fish meal prepared from the waste in the packing of sardines.

stituted for fish meal. The results of the experiment, which is designed to run for one year, are reported by Mr. Alfred R. Lee for a period of 32 weeks, as follows:

The mash fed consisted of one part each of bran, middlings, and fish meal and two parts of corn meal. In the check ration the fish meal was replaced by beef scrap. In addition, in each case a grain ration of equal parts of corn, wheat, and oats was fed. The beef scrap cost \$53 per ton and was guaranteed to contain from 50 to 55 per cent of protein. The price for fish meal used in the calculation of the comparative costs was \$46 per ton, a price recently quoted for a commercial article.

The yield of eggs from the pen fed on the ration containing fish meal averaged 113.1 per hen, at a cost of 7.1 cents per dozen and with a food consumption of 44.1 pounds per hen. The average number of eggs per hen in the pen fed on the beef-scrap ration was 128.4, at a cost of 7.8 cents per dozen and with 55.7 pounds of food eaten. Estimating the value of the eggs at 30 cents per dozen, the profit from the pen fed on beef scrap would exceed that of the pen on fish meal by \$2.48, or about 14 cents per hen, on account of the greater production in the former pen. At a price slightly under that quoted, fish meal would have been as profitable as beef scrap.

At the present time the hens have eaten the beef scrap a little more freely and have given a slightly greater egg yield. No differences were noted in regard to size or flavor of the eggs or the health and weight of the fowls.

Similar results in regard to freedom from taint of fish in eggs were obtained by a manufacturer of poultry feeds who tested one of the experimental lots of meal prepared from the sardine waste. This particular lot of meal contained 17.51 per cent of fat and had no deleterious effect on the quality of the eggs.

PIGS.

A portion of the meal as used for feeding to cows and in compounding the ration fed to the poultry, was compared with tankage as a supplementary feeding stuff for growing and fattening pigs. This experiment was conducted by Mr. F. G. Ashbrook of the Animal Husbandry Division, Bureau of Animal Industry, who makes the following report of the work:

The experiment was conducted to determine the comparative values of fish meal and tankage as supplements in a ration for growing and fattening pigs.

The pigs used in this work were grade Berkshires, averaging 52.3 pounds per head when the experiment started. They were as uniform in size, age, and breeding as it was possible to obtain.

For purposes of calculation the feeds used were estimated to cost as follows:

Corn, 70 cents per bushel, plus \$2 per ton for grinding, making \$27 per ton.

White middlings, \$30 per ton.

Digester tankage (60 per cent protein), \$50 per ton.

Fish meal, \$35 per ton.

It should not be assumed that this price is to establish arbitrarily a price for fish meal. As dried fish products have so largely been sold as fertilizers, it was thought that the price would to some extent be governed by the condition of the fertilizer market.

The guaranteed analysis of the tankage was:

	Per cent.
Protein	60
Fat	8
Phosphoric acid	8
Crude fiber	3

The feeding period was divided into two parts. First, a growing period of 112 days from weaning up to a fattening age, starting January 19, 1915, and ending May 11, 1915. Second, a fattening period of about one month, starting May 11, 1915, and ending June 8, 1915. The pigs at this date averaged a little better than 250 pounds and had to be sold.

Procedure.—The 12 pigs for the first period were divided into two lots. Lot No. 1, check lot, was composed of 8 pigs; lot No. 2 was composed of 4 pigs. During the first period, the pigs were fed as indicated below.

RESULTS DURING THE GROWING PERIOD.

The pigs, which were all in good, thrifty, growing condition, were about 3 months of age at the beginning of the experiment, and in order to accustom them to their surroundings they were fed in dry lot from the time they were weaned until the experiment was begun. The pigs in both lots were so fed that all the feed, which was in the form of a thin slop, was cleaned up at each feeding, thereby insuring a sharp appetite at the next feeding time. There was no trouble whatever in getting the pigs to eat the ration containing fish meal.

Growing period: Jan. 19, 1915, to May 11, 1915 (112 days).

Lot 1. Ration: 4 parts corn meal, 4 parts middlings, 1 part tankage:

Duration of experiment.....	days..	112
Pigs.....	number..	8
Average first weight.....	pounds..	51.37
Average final weight.....	do....	191.50
Average gain per pig.....	do....	140.13
Daily gain per pig.....	do....	1.25
Total grain fed.....	do....	4,060.5
Average grain eaten per pig daily.....	do....	4.53
Grain per 100 pounds gain.....	do....	362
Cost of 100 pounds gain.....	dollars..	5.58

Lot 2. Ration: 4 parts corn meal, 4 parts middlings, 1 part fish meal:

Duration of experiment.....	days..	112
Pigs.....	number..	4
Average first weight.....	pounds..	54.25
Average final weight.....	do....	201.50
Average gain per pig.....	do....	147.25
Daily gain per pig.....	do....	1.31
Total grain fed.....	do....	2,152.5
Average grain eaten per pig daily.....	do....	4.80
Grain per 100 pounds gain.....	do....	365
Cost of 100 pounds gain.....	dollars..	5.22

During the growing period the lot fed corn meal, middlings, and fish meal made a greater daily gain and a cheaper gain than the lot receiving the tankage supplement. The lot receiving the fish-meal supplement consumed 122.3 pounds more feed, gained a total of 28.5 pounds more, and cost 36 cents less per 100 pounds of gain, than did the lot to which tankage was fed. At the close of the

growing period the average weight of the pigs fed fish meal was 201.5 pounds, while that for the pigs getting the tankage supplement was 191.5 pounds, a difference of 10 pounds. From observation there could be noted no difference between the two lots with respect to growth in the way of general development, which would indicate that one ration was not particularly superior to the other in meeting requirements for growth in pigs.

These same 12 pigs were used for the second period and were divided into lots and fed as follows:

Lot No. 3, composed of the same four pigs as lot No. 2 (in the growing period), was continued on the same ration, which consisted of: 4 parts of corn meal, 4 parts of middlings, 1 part of fish meal.

Lot No. 4, composed of four pigs from lot No. 1, was fed a ration of: 9 parts of corn meal, 1 part of fish meal.

Lot No. 5, composed of four pigs from lot No. 1, was fed a ration of: 9 parts of corn meal, 1 part of tankage.

RESULTS DURING THE FINISHING PERIOD.

At the close of the 16 weeks' growing period the hogs were divided into different lots in order to have them as uniform as possible for the finishing period. Lot 2 in the growing period was lot 3 in the fattening period. This lot was fed the same ration as in the growing period—4 parts corn meal, 4 parts middlings, 1 part fish meal. There are many farmers who feed the same ration both for the growing and fattening periods, and it was the intention to carry out such a scheme with this lot of hogs in order to determine the advisability of such a practice.

Fattening period: May 11, 1915, to June 8, 1915 (28 days).

Lot 3.—Ration: 4 parts corn meal, 4 parts middlings, 1 part fish meal:

Duration of experiment.....	days..	28
Pigs.....	number..	4
Average first weight.....	pounds..	201.5
Average final weight.....	do....	255.25
Average gain per pig.....	do....	53.75
Daily gain per pig.....	do....	1.91
Total grain fed.....	do....	903
Average grain eaten per pig daily.....	do....	8.06
Grain per 100 pounds gain.....	do....	421
Cost of 100 pounds gain.....	dollars..	6.04

Lot 4.—Ration: 9 parts corn meal, 1 part fish meal:

Duration of experiment.....	days..	28
Pigs.....	number..	4
Average first weight.....	pounds..	191.5
Average final weight.....	do....	251.75
Average gain per pig.....	do....	60.25
Daily gain per pig.....	do....	2.16
Total grain fed.....	do....	956
Average grain eaten per pig daily.....	do....	8.54
Grain per 100 pounds gain.....	do....	393
Cost of 100 pounds gain.....	dollars..	5.35

Lot 5.—Ration: 9 parts corn meal, 1 part tankage:

Duration of experiment.....	days..	28
Pigs.....	number..	4
Average first weight.....	pounds..	192.0
Average final weight.....	do....	248.00
Average gain per pig.....	do....	54.00

Lot 5.—Ration: 9 parts corn meal, 1 part tankage—Continued.

Daily gain per pig.....	dollars..	2.00
Total grain fed.....	do....	910
Average grain eaten per pig daily.....	do....	8.13
Grain per 100 pounds gain.....	do....	462
Cost of 100 pounds gain.....	dollars..	6.76

The lot fed corn meal, middlings, and fish meal during the finishing period did not consume as much feed as the lot fed corn and fish meal or the lot fed corn meal and tankage. The cost of producing 100 pounds grain in the lot fed corn meal, middlings, and fish meal was 72 cents less than in the case of the lot fed corn meal and tankage; both lots, however, were about equal with respect to the average gain per pig during this period. The lot fed 9 parts of corn meal and 1 part of fish meal made a better showing than either of the other lots in the rate of gain, pounds of feed fed per 100 pounds gain, and the cost of 100 pounds gain.

CONCLUSIONS.

From this experiment the conclusion is justified that fish meal is a very effective supplement to a grain ration for pigs. Hogs relish it and are extremely fond of it, principally because, like tankage, it is a flesh product.

In this experiment fish meal was superior to tankage in all comparisons, although the average daily gains and rate of gains in all three lots used in the experiment were exceptionally good.

Where fish meal can be obtained conveniently at a reasonable price and in suitable quantity it has a very considerable value in hog feeding.

The results of these feeding tests, which were highly satisfactory in all respects, indicate the value of fish meal as a supplementary feed.

The pigs which were fed fish meal received it during the growing period at the rate of 0.5 pound per head per day, and during the fattening period they received this meal at the rate of 0.85 pound per head per day. They made greater gains and at a less cost than those fed a ration containing tankage as a supplement. The animals relished the fish meal and maintained a thrifty growth, and were never off their feed during the entire time of the test period.

The pen of hens was fed on fish meal in the proportion of 20 per cent of the weight of the mash. During the period of the experiment, which was not completed at the time this was reported, there was a slight advantage in the actual yield of eggs in favor of the meat meal. No taint or flavor of fish was at any time detected in the eggs from the hens fed on fish meal.

Dairy cows fed on a ration containing fish meal, compared with cows fed on a similar ration in which fish meal was replaced by cottonseed meal, gave a greater yield of milk, but it contained a lower percentage of butter fat. However, the total amount of fat obtained was approximately the same in both cases. There was no detrimental effect on either the milk or the butter from feeding the fish meal.

GENERAL METHODS FOR THE MANUFACTURE OF FISH MEAL.

Fish meal may be made by the same general methods that are now employed in the preparation of fish scrap for fertilizer purposes; that is, by steam cooking of the raw material, pressing, and drying. The chief difference, which should be constantly borne in mind, is that the meal is to be used as a stock food and should therefore be prepared from raw material in a perfectly fresh state and under clean, sanitary surroundings.

A steam-jacketed retort cooker, or one in which the material is heated directly by steam, may be employed. There is also an automatic continuous cooker which serves very well for cooking the raw material.

Pressing of the material may be accomplished by means of the hydraulic press, the rack and cloth type of press, or by the automatic continuous screw press. The material should be pressed while hot, thus insuring the removal of the maximum quantity of oil.

There are several types of dryers suitable for drying the material, among which are the rotary dryers using direct heat or steam heat, and the stationary steam-jacketed dryers provided with a rotating shaft and blades for stirring the material. In the latter type preference should be given to the dryer providing for evaporation under vacuum. In the former type, the final dried product is in a granular form, which is very desirable when it is to be used as a poultry food. For use in other stock-food mixtures it would be preferable to have it finely ground. The revolving blades in the latter type grind the material during the drying process to a fairly fine meal, and for all ordinary purposes it should not require further grinding. In some cases where large fish are used, further grinding may be necessary to remove the eye balls and large bones. No attempt is made to recommend any particular type or kind of cooker, press, or dryer. These should be selected according to individual requirements, depending on the character and the quantity of the waste to be converted into meal. The prospective manufacturer of fish meal should thoroughly study all the different forms of apparatus mentioned above and select the type best suited to his particular needs. The more modern and later methods of manufacture should also be investigated.

A prominent feature in connection with the preparation of fish and fishery wastes into material for feeding purposes is the production of a very superior grade of fish oil. The oil rendered from raw material which of necessity must be in a perfectly fresh state of preservation for making into meal for stock food, cannot be compared with fish oil obtained from material in any stage of decomposition. The former oil would require but little refining, for in the

crude condition it has a bright, clear appearance, has very little fishy odor, and is free from rancidity. Its keeping qualities are excellent. Samples of large size obtained from the pressing of sardine waste have kept for over a year in as good condition, apparently, as when first prepared.

There is every reason for believing that the fish oil produced in the manufacture of fish meal is destined to become a valuable article, due to its far superior quality. At its present price the oil obtained at certain times of the season is sufficient to defray the cost of manufacture of the dried meal.

In the German market a fish meal containing a low percentage of oil (from 2 to 4 per cent) is considered the best grade of meal. On the Pacific coast the extraction of the oil by means of gasoline is being considered in the manufacture of fish meal in that locality. With a lower fat content a higher protein content is obtained, which is, of course, desirable. On the other hand, the fat, which is highly digestible, has a definite food value, and since it has been shown by experiment that high-grade fish meals of high fat content have been fed with no apparent taint being imparted to the final product, it is believed that the extraction of a fish meal to a fat content lower than that which could ordinarily be obtained by thorough and efficient pressing would be unnecessary. This is particularly apparent when it is considered that fish meal is to be used in relatively small quantities as a source of protein in balancing the rations of stock and in preparing the finished commercial stock feeds.

Further, it is believed that any trouble that may have been attributed to a high fat content in the meal probably was due to rank, rancid oil, developed in decomposing raw material. Such oil is not present in meal prepared from fresh, undecomposed fish and fish wastes. Certainly a fat content of 14.56 per cent in a meal of this character, as in that made from the waste in the packing of sardines, would appear to be satisfactory, since no flavor or taint of fish was imparted to eggs, milk, or butter in the experiments which were conducted with it.

Care on the part of the producer and purchaser should be exercised to make sure that the meal is of good quality, such as can only be obtained by preparation from wholesome, undecomposed raw material. A fish meal should not be manufactured from the waste and residues of salt fish. The excessive quantity of salt in such a meal may, when it is used for feeding purposes, result in harmful effects; and as a large amount of the protein compounds have been extracted by the salt, the resulting meal would be low in food value. With care and attention to sanitary features in its production, fish meal can be made one of the best and cleanest of feeding materials.

Conditions which obtain in plants where fish scrap for fertilizer is made, and the use of decomposed and putrid raw material, must not be permitted in the preparation of fish meal for feeding purposes. It is believed that fish meal, properly prepared, can be developed into one of the greatest sources of supply of high-protein stock feeds, and great care should be exercised not to ruin the possibilities at the very beginning of the enterprise by preparing and marketing an article unfit for feeding purposes.

It is suggested that the trade names, fish "scrap," fish "pomace," or fish "guano," be retained and be specifically applied to the product which is to be used as a fertilizer and which has been prepared with no great care in regard to factory cleanliness or to the degree of spoilage of the raw material, and that the name "fish meal" be applied to the product specifically prepared for feeding purposes.

OPINIONS OF THE TRADE IN REGARD TO FEEDING FISH MEAL.

The question of the use of fish meal by the trade was touched upon by correspondence with a number of the leading stock-food manufacturers at the time the experimental lots of meal were being prepared at Eastport, Me., during the sardine season of 1914. Samples of the meal and the analyses were submitted and the manufacturers were asked to express their opinion of it, and to state whether they had had any experience with the use of fish meal and whether they could use it in the preparation of a stock or poultry food.

Only two of the manufacturers had ever used fish meal and this was in compounding poultry mash. One firm which used it for this purpose stated they would be able to handle the entire output from the sardine industry. Several of the firms stated that in their opinion it would be valuable material for poultry feeds, while others were quite willing to try it for the manufacture of hog feed, stating that it should be able to replace tankage to good advantage, particularly if a more favorable price could be obtained.

Some doubted whether it could be used for a dairy feed on account of the fishy odor which might prevent the animals from eating it and because of the possibility of tainting the products. If it could be used for this purpose, it was the opinion of some that it would be a very valuable substance in preparing dairy feeds and a great boon to the dairy industry.

While only two of the firms had ever had any experience with the use of this material for feeding, they were all very much interested and made inquiries as to the amount of the material available, shipping classifications, and price. From this interest displayed and the favorable results obtained by its use, it would seem that a market should be assured for a good, well-prepared article.

RAW MATERIAL AVAILABLE FOR FISH MEAL.

There is already at hand a large amount of dried-fish product called fish "scrap" or "pomace" now used for fertilizer purposes, the marketing channel of which—or part of it, at least—could be turned in the direction of the stock-food manufacturing industry instead of into the fertilizer industry. This, however, can not be done until the product is prepared under conditions which would insure its safe use for feeding purposes. As previously pointed out, the value of this material as a fertilizer is not reduced by feeding it.

The menhaden fish "scrap" industry and the salmon, sardine, and tuna canning industries offer at the present time a large source of supply of fish meal, approximating 120,000 tons annually.

In 1912, 50,885 tons of dry fish fertilizer "scrap" and 37,536 tons of acidulated¹ "scrap" were produced in the menhaden fish-scrap industry.² The amount that could be obtained from the waste in the sardine industry will vary somewhat in different seasons. Assuming that the entire waste material would be converted into fish meal, it is estimated that from 2,000 to 4,000 tons per season could be prepared.

Thirty-five thousand to forty thousand tons per year of dry meal could be obtained from the utilization of the waste of the Pacific coast salmon canneries.³

Since the amount of waste in the salmon-canning industry that could be made into fish meal for feeding purposes is, at the present time, so far in excess of that of any other available supply, fish meal from this industry should soon become of importance in supplying the large western and middle-western area with this material. As before mentioned, fish meal for stock-feeding purposes is now prepared in limited quantities from the salmon-cannery waste.

No figures are at hand for estimating the amount which could be obtained from the tuna-canning industry or from the individual canneries of various fish products scattered throughout the country.

In addition to the amount that may be obtained from these sources a considerable quantity may be obtained from other fish not considered sufficiently good for food purposes, particularly the dogfish. This fish, the destruction of which is so much desired by all classes

¹ This acidulated fish "scrap" is prepared by adding sulphuric acid to the fresh stock. It seems hardly necessary to state that a meal prepared from material so treated should never be used for feeding animals. The prospective user should insist on a guaranty that sulphuric acid was not used in the preparation of meal or should have its absence established before using the meal for feeding purposes.

² Greer, "The Menhaden Industry of the Atlantic Coast," Bureau of Fisheries Document No. 811, p. 21.

³ Turrentine (U. S. Dept. Agr. Bull. 150, "Utilization of the fish waste of the Pacific Coast for the manufacture of fertilizer") estimates the total waste as 140,210 tons of raw material. By calculating on the basis of a 25 or 30 per cent yield of dry meal, the above figures were obtained.

of fishermen, could well be handled at small by-product plants attached to canneries, at the time of the preparation of meal from the waste, or in larger factories devoted entirely to the manufacture of meal. It would seem that in this new field for the use of fish meal for feeding purposes an outlet may have been found for the use of this outcast of the fish tribe and that it can at last be turned into material having a commercial and economic value.

The addition of this fish in liberal quantities to waste material from canneries, comprising heads, tails, fins, and only a small proportion of the meat portion of the fish, would greatly increase the feeding value of the resulting meal.

Attention should be called to the difference in composition—particularly of the protein material—of fish meal made from whole fish or from waste containing a large portion of the edible part of the fish, and of a fish meal prepared from waste composed entirely of the heads, tails, and fins. In the latter case gelatin or glue derived from the collagen of the cartilage, bones, and fins, will predominate as the protein constituent, and a meal thus prepared will not have so high a feeding value as one in which the protein derived from the meat or flesh of the fish predominates.

In instances where waste deficient in the protein constituents of whole fish is available, the dogfish will serve to good advantage as a means of supplying this deficiency and will increase the content of essential tissue-building material.

GENERAL CONCLUSIONS.

The universally favorable results obtained in the feeding of fish meal appear to warrant its extended use as a supplementary feeding stuff.

Laboratory tests have shown that the coefficients of digestibility of the principal constituents of fish meal—the protein and fat—are high, and the feeding experiments have all shown it to be as valuable as many other high-protein concentrates with which it has been compared.

From the feeding experiments it appears that there has not been just cause for the assumption that the feeding of fish meal of good quality imparts a fishy taint to such products as milk, butter, eggs, and meat. When the meal is fed in proper quantities, as a supplementary feed with other feeds, apparently no deleterious effects are noticeable in regard to taint or flavor of fish. There is a possibility that it may impart its flavor to the products of animals or fowls when it is fed to them in too large quantities. Even under these circumstances its use would be warranted, as the feeding of the meal can be discontinued a sufficient length of time during the final fattening period to eliminate any objectionable taint.

An enormous field is opened up to the various fishing industries for the preparation of a valuable material either from waste residues or from whole fish and for the utilization of this material to better advantage than heretofore. Likewise for the farmer, stock raiser, and poultry man, a hitherto neglected source of supply of a high-protein feeding stuff is available.

In the light of the recorded experiments on the use of this material for feeding purposes and the feeding tests with the herring meal prepared from the sardine waste, conducted in this department, it is believed that all doubts as to the feasibility of using fish meal as a feeding stuff may be dispelled, and it is confidently expected that in time it will take its place as one of the leading protein concentrates used as a supplementary stock food.

As a final conclusion in regard to the subject of fish meal as a stock food it can be said to those who may be interested in producing this material that there is a great need and a splendid opportunity in the market for it.

To those who may be interested in using the product it can be said that fish meal is as valuable as other widely used high-protein feeding stuffs, and in some instances has been proved more valuable than these; that it does not impart its flavor to animal products if fed in reasonable amounts in conjunction with other foods; and, finally, that it should be given consideration whenever a high-protein foodstuff is required.

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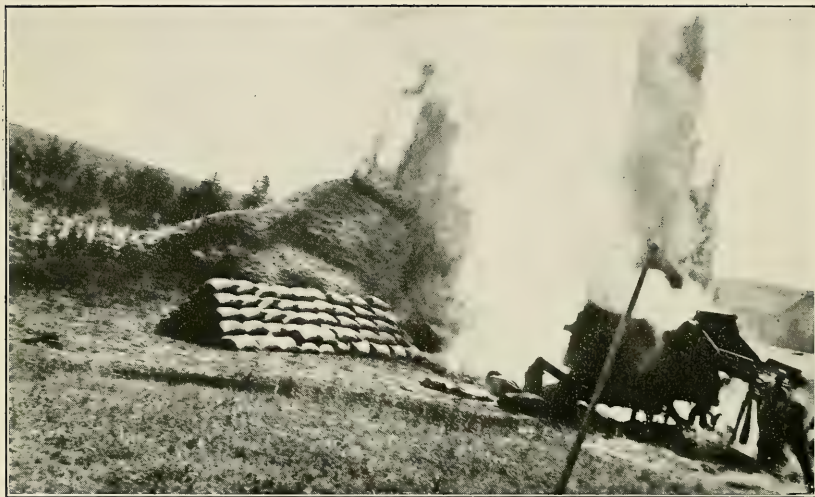


FIG. 1.—SMUT-DUST EXPLOSION IN THRESHING MACHINE IN EASTERN WASHINGTON. PHOTOGRAPH WAS TAKEN AT TIME EXPLOSION AND FIRE OCCURRED.

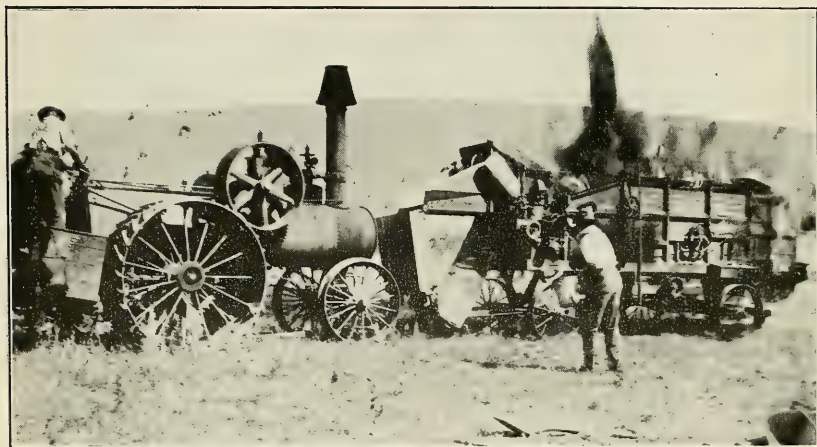


FIG. 2.—ENGINE PULLING A MACHINE AWAY FROM STRAW STACK AFTER EXPLOSION AND FIRE.



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BULLETIN No. 379

Contribution from the Bureau of Chemistry
CARL L. ALSBERG, Chief, and the
Office of Public Roads and Rural Engineering
LOGAN WALLER PAGE, Director



Washington, D. C.



August 4, 1916

DUST EXPLOSIONS AND FIRES IN GRAIN SEPARATORS IN THE PACIFIC NORTHWEST.

By DAVID J. PRICE, *Engineer in Charge of Grain Dust Explosion Investigations, Bureau of Chemistry*, and E. B. McCORMICK, *Chief, Division of Rural Engineering, Office of Public Roads and Rural Engineering*.

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INTRODUCTION.

The large number of fires and explosions in grain separators during the threshing process has awakened unusual interest in the Pacific Northwest during the last two seasons. These fires and explosions were most frequent in the wheat-growing territory in eastern Washington and northern Idaho, although occasional occurrences were reported in adjoining territory in northeastern Oregon. From reports received from various sources it is apparent that similar explosions and fires have occurred in scattered localities throughout the territory west of the Mississippi River.

The Department of Agriculture had for some time been conducting studies relative to the causes and prevention of dust explosions in grain mills, elevators, and similar plants. The close relation of thresher explosions to the general study of grain-dust explosions led to the inauguration of a special study of this allied problem in the northwestern field during the 1915 season. As a result of this study 166 occurrences were investigated and reported. It is probable that many other explosions and fires took place which were not brought to the attention of the department.

The results of the investigation indicate that the wheat crop contained a large percentage of smut and that the explosions and fires in many cases were due to the formation of an explosive mixture of smut dust and air and the ignition of this mixture by static electricity during the threshing operations. This report briefly summarizes the results of the field work relative to the causes of ignition and describes the various preventive devices developed as a result of the investigation.

PLAN OF INVESTIGATION.

ORGANIZATION.

The field work was conducted under a cooperative arrangement between the Bureau of Chemistry, where the general study of grain-dust explosions is being carried on, and the Office of Public Roads and Rural Engineering. Investigators were assigned to the various parts of the territory affected and a central office was opened in the Federal building at Spokane, Wash. J. E. Young, assistant agricultural engineer, conducted field investigations in the vicinity of Walla Walla and Rosalia, Wash., and J. C. Woodson, assistant agricultural engineer, in the territory adjacent to Moscow, Idaho. H. H. Brown, assistant chemist, was assigned to investigations in the vicinity of Colfax, Wash. The organization and direction of the field work and the conduct of the investigation were in charge of David J. Price, engineer, of the Bureau of Chemistry, and E. B. McCormick, mechanical engineer, of the Office of Public Roads and Rural Engineering.

COOPERATION WITH THE UNIVERSITY OF IDAHO.

The investigations in northern Idaho were conducted in cooperation with the University of Idaho at Moscow, represented by Prof. N. S. Robb, of the Department of Farm Crops. Office room, laboratories, and electrical apparatus were placed at the disposal of the investigators and experimental work was conducted in conjunction with Prof. Angell, of the Department of Physics. The staff was much interested in the explosion problem in its territory and rendered valuable assistance during the conduct of the investigations.

CONFERENCES WITH THE STATE COLLEGE OF WASHINGTON.

Conferences were held at the beginning of the investigations with Dr. Ira D. Cardiff, director of the experiment station, State College of Washington, Pullman, Wash., and members of the staff. This problem had been studied by the station staff in 1914 and the results published in bulletin form.¹ During the conduct of the field work

¹ Washington Station Bulletin No. 117, Nov. 3, 1914. Report on Fires Occurring in Threshing Separators in Eastern Washington during the Summer of 1914.

various phases of the problem were considered with the State College staff.

CONDUCT OF INVESTIGATIONS.

Although investigations by the Department of Agriculture were not conducted in the field during the 1914 threshing season, samples of wheat smut dust from the Pacific Northwest were obtained at the close of the season. Experiments at that time indicated that the material was highly inflammable and might be associated with the frequent fires and explosions in grain separators.

The entire season extending from the first week in July to the middle of September, 1915, was spent in field work in the territory. Effort was made to visit the scene of each explosion or fire as soon as possible after it had taken place and obtain all the available information pertaining to the occurrence. Arrangements previously had been made so that prompt reports could be received at the Spokane office, through various channels, and also by the men in the field, so that no time would be lost in reaching the scene of the explosion. In nearly 150 cases the investigator was on the ground either immediately or within a few hours after the occurrence. In many instances the explosions were so sudden and violent that the crew could give very little information, but it was possible in the majority of cases to make valuable deductions. A large percentage of the thresher owners would not advance an opinion, but many of them believed that matches or explosives had been placed in the bundles. In many cases, however, this was mere conjecture and not supported by evidence.

CLASSIFICATION OF EXPLOSIONS.

TERRITORY AFFECTED.

The largest number of the 166 explosions reported occurred in the counties of Whitman and Spokane in eastern Washington, and the counties of Latah, Lewis, Kootenai, and Nez Perce, in northern Idaho. Eighty-three per cent of the total number of explosions and fires reported occurred in this district. Of these 70 per cent occurred in Washington and 13 per cent in Idaho. About 11 per cent of the total number reported occurred in the Big Bend section in the Columbia River Valley in Washington, comprising the counties of Adams, Lincoln, Grant, and Douglas. The remaining explosions occurred in Walla Walla, Garfield, Yakima, and Klickitat Counties. The field investigations, however, generally were confined to the Palouse country in eastern Washington and the northern Idaho territory.

FREQUENCY OF EXPLOSIONS.

The explosions began with the opening of the season in the Big Bend country about the middle of July and continued until the

middle of September. They increased in frequency as the season progressed until it was not unusual to have from 6 to 10 a day. On both August 11 and August 16 there were 11 explosions and fires reported, and the total for the week from August 9 to 14 reached 46, an average of between 6 and 7 a day. The explosions were classified by days and weeks as follows:

July 12-17-----	1	Sept. 20-----	1
July 19-24-----	3		
July 26-31-----	6		166
Aug. 2-7-----	32	July-----	10
Aug. 9-14-----	46	August-----	149
Aug. 16-21-----	33	September-----	7
Aug. 22-28-----	29	Maximum, one week-----	46
Aug. 30-Sept. 4-----	13	Maximum, one day, Aug. 10, 16---	11
Sept. 6-11-----	2		

CLASSIFICATION BY TIME OF DAY.

The explosions and fires occurred at all times during the day. The following tabulation shows the time of 128 occurrences:

5 to 6 a. m.-----	5	2 to 3 p. m.-----	14
6 to 7 a. m.-----	5	3 to 4 p. m.-----	13
7 to 8 a. m.-----	3	4 to 5 p. m.-----	12
8 to 9 a. m.-----	3	5 to 6 p. m.-----	17
9 to 10 a. m.-----	9	6 to 7 p. m.-----	17
10 to 11 a. m.-----	4	7 to 8 p. m.-----	5
11 to 12 noon-----	10		
12 to 1 p. m.-----	3		128
1 to 2 p. m.-----	8		

From this it will be noted that the greatest number of explosions occurred between the hours of 1 and 7 p. m.

MAKE OF MACHINES.

The explosions were generally distributed among all types of separators operated in the territory and were not confined to any one make or type. It was thought that possibly the explosions and fires were confined to stationary machines, but investigators learned that there were at least three occurrences in the "combine" type.

The investigation shows that the explosions occurred in both steel and wooden separators. In view of the fact that data are not available to determine the number of machines of each type in the territory, it is impossible to state the percentage of each affected.

NATURE OF EXPLOSIONS.

The nature of the explosions and fires in 117 cases can be summarized as follows:

<i>Explosions.</i>		<i>Fires.</i>	
Sudden puff-----	68	Without explosions-----	21
Very violent-----	8	Nature not determined-----	1
Small puff-----	10		
Slight explosion-----	2		22
Muffled and quick-----	5		
Flame followed by explosion-----	1		
Detonation report-----	1		
	95		

This table indicates that at least 95 of the occurrences, or 81 per cent, were dust explosions. In the remaining cases where there was sufficient flame to damage the machine the fire was not accompanied by as loud reports as in the other instances. The ignition was not so rapid and the rate of burning accordingly slower.

POINT OF ORIGIN OF EXPLOSIONS.

Special efforts were made by the investigators to locate the point of origin of the explosions and fires. The results in 108 cases can be summarized as follows:

Back of cylinder or near this point-----	82	Grain pan-----	1
Entire machine-----	9	Straw stack-----	1
Behind knives-----	5	Back of machine-----	1
Blower-----	4	Engine-----	1
Center of machine-----	2		108
Front of machine-----	2		

At least 82 of these occurrences, or 76 per cent, originated back of the cylinder or very near this point, indicating that the source of ignition in a large majority of cases was near this part of the separator.

LOCAL OPINION AS TO CAUSES.

During the preliminary field investigations an effort was made to interview the thresher agents of the various companies in the vicinity of Spokane and other interested parties with a view to obtaining information pertaining to the local opinion regarding causes of previous explosions and fires. Prior to 1914 occasional occurrences of this nature had taken place throughout the Pacific Northwest, but until 1914 general interest was not awakened. During that year, owing to the frequency of the explosions and fires, local interest was greatly increased.

Early results prior to the opening of the threshing season indicated that opinion as to the cause of explosions and fires of this nature was divided between natural causes and incendiarism. The principal reason advanced for this latter conclusion was that prior to the 1914 season explosions were not very frequent. This led to the conclusion that means were being taken maliciously to destroy the separators by introducing matches and explosives into the grain bundles.

The following summary indicates the local opinion advanced as to the causes of 121 explosions personally investigated during the 1915 season:

Matches, incendiary, and accidental.....	60	Crowding machine	1
Not given, and indefinite.....	14		121
Foreign material, sparks from same.....	14		
Smut explosion.....	14		Per cent.
Static electricity.....	10	Believed to be incendiary.....	49
Powder or explosives.....	4	Foreign material.....	11
Engine sparks.....	2	Smut explosion.....	11
Bent spikes.....	1	Static electricity.....	8.2
Hot boxes.....	1	Not given.....	11

In connection with obtaining the opinions of the local thresher men and the grain owners, a special effort also was made to secure any evidence sustaining the conclusions advanced. In the great majority of cases there was no definite reason for supporting the conclusion which was based frequently on current rumors. In some cases, however, matches were found in the grain pan, but it was impossible to determine whether they had fallen into the machines accidentally or had been introduced intentionally.

RESULTS OF FIELD INVESTIGATION.

SUMMARY OF INVESTIGATORS' OPINIONS.

In each explosion and fire the investigator summarized the evidence obtainable, and after careful consideration of all information available assigned the cause most probable in his opinion. The following summary shows the conclusions reached in 94 special cases investigated:

Static electricity.....	45	Incendiary.....	1
Smut explosion.....	25	Beater striking conveyor.....	1
Friction sparks.....	10	No clue.....	1
Matches.....	5		
Doubtful.....	5		94
Teeth striking.....	1		

About 75 per cent of the occurrences were assigned to the presence of static electricity and to smut explosions. The percentage assigned

by the investigators as indicating incendiary origin was very small as compared with that advanced by local men.

PERCENTAGE OF SMUTTED HEADS.

The percentage of smut present in the wheat crop was determined in each case by taking a sample of a known number of heads and separating it into two parts, one part consisting of those heads which were not affected by smut, the other part of those heads which were affected. The proportion of smutted heads to the whole number of heads in the sample gave the percentage of smutted heads present in the crop.

Of 112 explosions nearly all occurred during the threshing of grain which contained from 1 to 35 per cent of smutted heads; the average percentage in 108 explosions was 15. There were only three explosions in fields reported to contain no smut.

Percentage of smutted heads.	No. of ex- plosions.	Percentage of smutted heads.	No. of ex- plosions.
No smut.....	3	15 to 20 per cent.....	20
Less than 1 per cent.....	4	22 to 25 per cent.....	8
1 to 5 per cent.....	19	25 to 30 per cent.....	7
5 to 10 per cent.....	27	30 to 35 per cent.....	5
10 to 15 per cent.....	15	Not known.....	4

SIZE OF MACHINE.

The results of the investigation in relation to the size of machines affected indicate that explosions occurred in all kinds and types of machines, irrespective of size.

SPEED OF CYLINDER.

The fact that many explosions occurred while the separator was being operated at the cylinder speed recommended by the manufacturers indicates that operation of the machine at excessive speed is not essential to produce an explosion.

POWER USED.

The kind of power used in operating the machine was of special importance, since one of the early suggestions as to cause was that engine sparks were responsible. It was found that explosions and fires took place in gasoline-driven as well as in steam-driven outfits, and that the cause of ignition was within the machine itself and not external. In 113 machines investigated the power used was as follows:

Gasoline.....	18	Electric motor.....	1
Steam.....	93	Horses.....	1

As the largest number of machines in the territory were operated by steam power the figures just given do not indicate that steam-driven outfits are more subject to explosions than are other types. They do, however, discount the theory that explosions occurred only in machines operated by steam power.

HOT BOXES.

The frequent occurrence of hot boxes around the machine also was assigned as a cause for many of the explosions. It was asserted that the boxes were allowed to become hot and helped to set fire to the machine.

The investigators endeavored to obtain information relative to the presence of hot boxes, but the difficulties encountered along this line were increased by the fact that the average operator was not willing to admit that hot boxes occurred frequently in his machine. At the time of the investigation it was difficult to determine definitely whether a boxing had been melted by the fire or had been heated to the melting point before the fire started. During the conduct of the field investigations personal observation of machines while running indicated that a large number of boxings run hot all the time. In some cases the "oiler" could be seen carrying water from the engine and pouring it on the boxes. The results of 113 investigations based on statements of separator men can be summarized as follows:

No hot boxes.....	72	One to three each day.....	2
Occasional.....	33	One to two each day.....	1
One each day.....	5		

Although difficulty was encountered in obtaining data which were considered authentic, the investigations show conclusively that the presence of a hot box is not essential in order that an explosion may take place. This does not mean that a hot box may not be a contributory cause to an explosion if the heat generated is of sufficient intensity and so located as to cause ignition.

DAMAGE TO SEPARATOR.

The damage to the separators varied from very slight damage to total destruction. In cases where fire-fighting equipment had been provided the damage was much smaller than in the machines where no precautions had been taken. In 146 explosions and fires the results can be summarized as follows:

	No. cases.	Per cent.		No. cases.	Per cent.
Complete loss	40	27.4	Slight damage	20	13.7
Partial loss	49	33.6	No damage	37	25.3

The total damage reported for all machines was about \$60,000. In many cases after complete loss the owner was compelled to discontinue threshing for the season, and a serious situation was threatened unless some remedy was found.

DAMAGE TO GRAIN.

In almost all cases the flame from the explosion and fire was blown into the straw pile, and in many instances spread to the stacked grain and also to the unthreshed grain in the field. As a result sev-



FIG. 1.—THRESHING WHEAT NEAR MOSCOW, IDAHO, WITH 8 PER CENT SMUT (ESTIMATED) IN CROP.

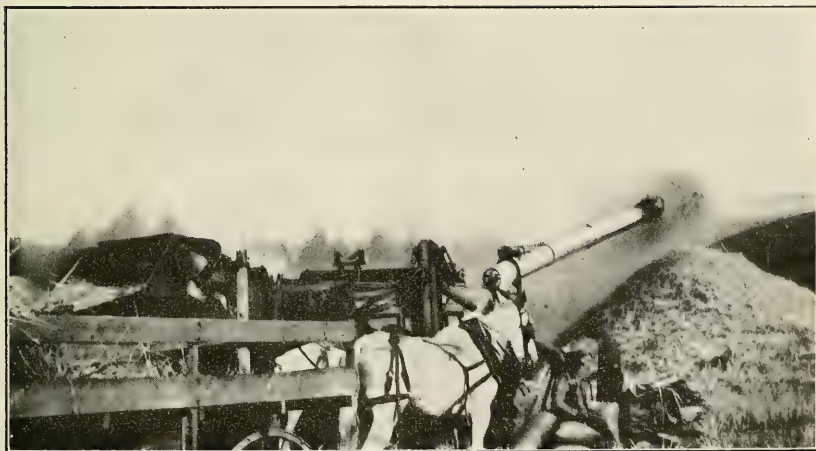


FIG. 2.—SAME MACHINE THRESHING WITH 14 PER CENT SMUT (ESTIMATED) IN CROP, SHOWING BLACKER SMUT-DUST CLOUD COMING FROM BLOWER PIPE.



FIG. 1.—BLACK SMUT-DUST CLOUD COMING OUT OF BLOWER PIPE DURING THRESHING OF SMUTTY WHEAT IN EASTERN WASHINGTON.

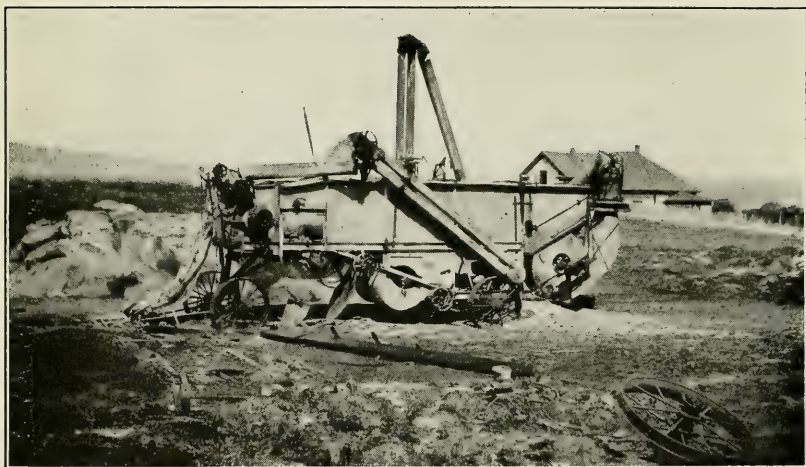


FIG. 2.—STEEL MACHINE BADLY DAMAGED BY SMUT EXPLOSION AND FIRE IN EASTERN WASHINGTON.

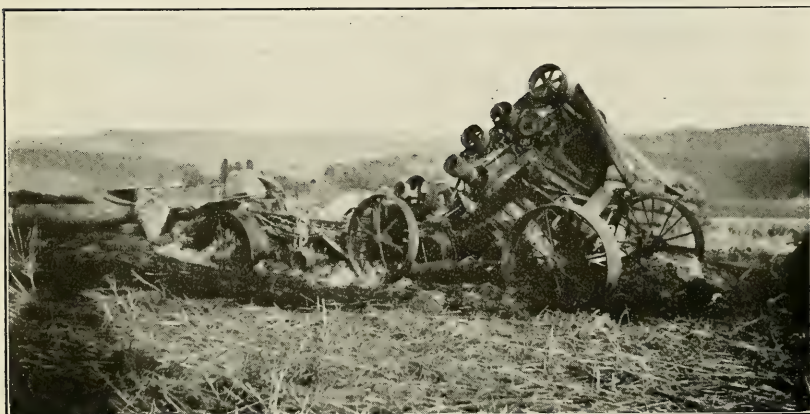


FIG. 3.—WOODEN MACHINE COMPLETELY DESTROYED BY SMUT EXPLOSION AND FIRE IN PACIFIC NORTHWEST.



FIG. 1.—WOODEN MACHINE, AFTER EXPLOSION AND FIRE.

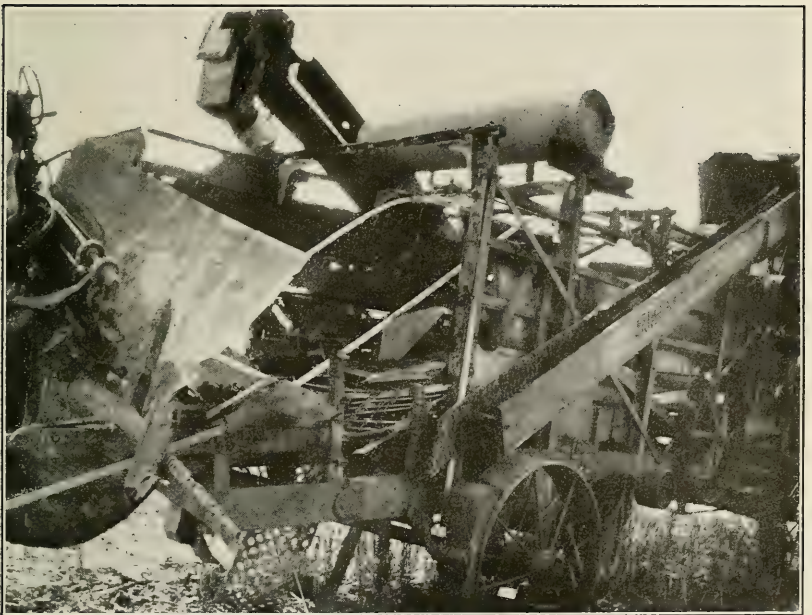


FIG. 2.—ANOTHER VIEW OF SAME MACHINE, SHOWING EXTENT OF DAMAGE.

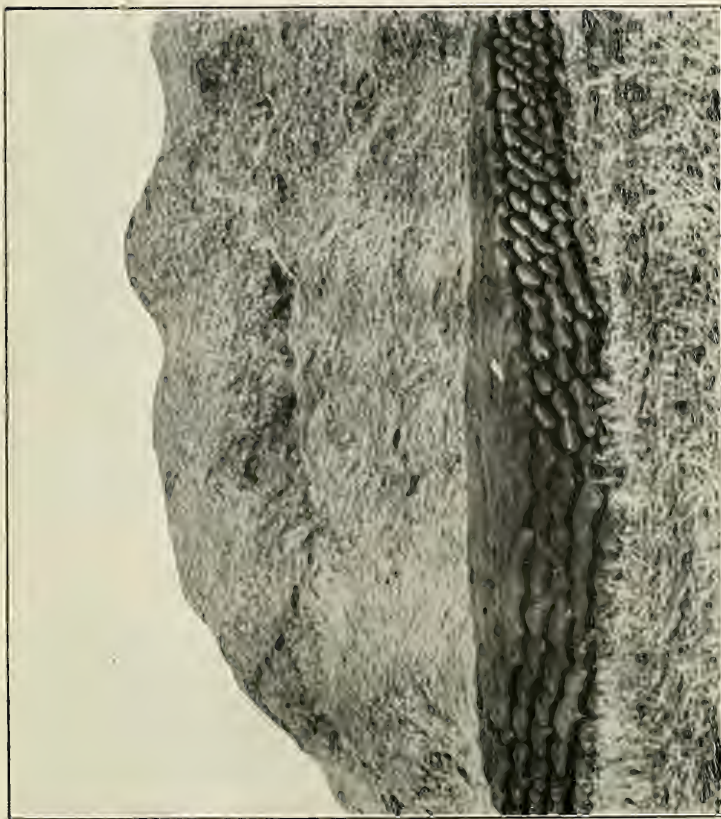


FIG. 1.—PILE OF 1,250 SACKS (3,000 BUSHELS) OF WHEAT THRESHED IN NORTHERN IDAHO. THE SACKS ARE PILED IN THE FIELD AND THEN HAULED TO GRAIN WAREHOUSE FOR MARKET.



FIG. 2.—INVESTIGATORS MEASURING DISCHARGES OF STATIC ELECTRICITY FROM STEEL MACHINE.

eral hundred acres of grain were destroyed. The grain loss in the fires investigated reached about \$50,000.

MACHINES WITH FIRE-FIGHTING EQUIPMENT.

A large number of the machines in which fires occurred were provided with some fire-fighting equipment, as is shown in the following summary:

	No. cases.	Per cent.		No. cases.	Per cent.
No fire-fighting equip-			Chemical extinguish-		
ment-----	28	24.8	ers-----	29	25.6
Water, steam, etc-----	43	38.1	Water tanks-----	13	11.5

From this summary it will be seen that less than 25 per cent of the machines were not equipped with fire-fighting apparatus. Since the percentage of machines that suffered a total loss (27.4 per cent) is in about the same proportion, it is reasonable to conclude that the fire-fighting equipment was effective, especially so since in the majority of cases where the machines were totally destroyed no preventive means had been installed to check the progress of the fire and explosion.

STATIC ELECTRICITY AS A CAUSE OF EXPLOSIONS.

THRESHING-MACHINE EXPLOSIONS.

It was evident from the beginning of the investigation that a large quantity of static electricity was generated during the operation of the separator. Workmen admitted that on certain days static electricity was noticeably present around the machines.

One case in which the owner thought the presence of static electricity was responsible occurred in Latah County, Idaho. This machine was new, having been operated but part of a day. It was completely destroyed as a result of the explosion. As the outfit was located 15 miles from a railroad and 4 miles from the county road there was no reason to suspect incendiarism. The crew was composed of neighbors, or men known to be reliable. There was 19 per cent smut (estimated by counting the smutted heads) in the crop. The weather was very hot and dry. After summarizing the evidence, the investigator concluded that it was clearly a case of smut explosion by electrostatic ignition.

A similar case occurred in Whitman County, Wash. The owner had experienced two fires, one in the evening and the other the following morning, neither of them causing much damage to the separator but destroying the surrounding grain in the field and the threshed grain in sacks. At the time of the occurrence the machine was threshing wheat with 31 per cent smut and was located 21 miles from the railroad and several miles from the county road.

The evidence available convinced the investigator that the explosion was due to ignition of smut dust by static electricity.

In another case the owner of a machine which was destroyed stated that he was standing at the engine and was looking directly at the cylinder at the time of the explosion. He could see the cylinder itself, as the feeding had stopped momentarily. He observed a long blue spark coincident with the explosion. In other investigations the men in charge of the machines stated that there were large quantities of static electricity present around the machine preceding the explosions.

In one case the owner of the machine stated that his machine was very heavily charged with static electricity on the morning of the explosion, to such an extent that it was not possible to touch any metal part without getting a shock. This condition had never been noticed on this particular machine before. The explosion was violent in nature and totally destroyed the machine.

MILL EXPLOSIONS.

Previous investigations relative to the causes of explosions in grain mills and elevators and similar plants indicated that static electricity was a possible factor in the production of dust explosions.

In September, 1913, at the time investigations were being conducted in cooperation with the Millers' Committee of Buffalo, N. Y., two slight explosions occurred on a dry, frosty morning in early fall, in two separate plants in western New York, at a time when the feed had been shut off from certain grinding machines. Both occurrences took place a considerable time after the stream of grain had stopped entering the machines. The possibility of static electricity being generated by the operation of the revolving plates of the machine suggested itself in a very preliminary way at the time of these explosions, and a confidential report was prepared and presented at the time to the Millers' Committee. Although up to that time no record could be found that experiments had been conducted to determine whether cereal dusts could be ignited in this manner, it was found by experiment that sufficient static electricity could be generated by the friction of a very small pulley and belt to ignite natural gas readily. It was learned at this time that a milling company in the South, engaged in grinding cottonseed cake into meal, after experiencing a series of explosions, had prevented a repetition of these occurrences by grounding the machine by means of a wire connected to a rod driven into the ground near by.¹ This seemed to confirm

¹ Preliminary Report on the Explosibility of Grain Dusts. Cooperative Investigation by Millers' Committee, Buffalo, N. Y., under the direction of Dr. George A. Hulett, Chief Chemist, U. S. Bureau of Mines. By David J. Price and Harold H. Brown. Pittsburgh, 1914.

the original theory and indicated the value of a grounding device of this kind.

The possibility of static electricity as a source of cereal dust ignition was very clearly established by an explosion in the dextrine department of a starch factory in one of the Eastern States (in September, 1914). The origin of this explosion was traced to the generation of static electricity by friction of particles of dextrine on an 80-mesh brass gauze surrounding a revolving reel. This reel was revolving at the rate of only 16 revolutions per minute when the explosion occurred.

At the time of the explosion this reel was grounded to an overhead sprinkling system. During the investigation which followed, however, it was found that the connection was made from the journal box, and that a heavy film of fresh oil surrounded the shaft. This was thought to have served to insulate the shaft and allow the static electricity to accumulate within the reel until there was sufficient charge to ignite the dust.

An English scientist has determined that if a cloud of dust is blown against an insulated conductor (a wire, for instance) the wire becomes charged with electricity, and under certain conditions may become so highly charged as to give off sparks.¹

EXPERIMENTAL FIELD AND LABORATORY WORK.

METHODS OF GROUNDING MACHINES IN EXPERIMENTAL WORK.

From results that had previously been obtained by grounding machines effectively in various branches of the milling industry and also by some machine operators in the Northwest, it was decided to conduct experimental work along this line with the grain separators, in an attempt to carry off any static electricity that might be generated during the operation of the machine.

The experimental work in developing a satisfactory grounding device was conducted along three distinct lines, as follows:

1. Separately grounding each part, either directly or through its bearing.
2. Connecting wires from all moving parts to one wire and grounding that wire.
3. Wiring all moving parts to some metallic portion of the separator of sufficient magnitude to act as a ground.

DESCRIPTION OF VARIOUS METHODS.

First method.—The first method was perhaps the most common among the thresher men who were inclined to accept the theory that

¹ Philosophical Magazine, London, 6 (1913), p. 481-494. "On the Electrification Associated with Dust Clouds," by W. A. Douglass Rudge, Professor of Physics, University College, Bloemfontein.

static electricity was responsible for the smut dust ignition. The method usually adopted was to connect a No. 12 or 14 weatherproof copper wire to the journal box of the cylinder shaft and to an iron rod driven into the ground, and to make similar connection with the bearing of the stacker fan.

The arrangement was identical with the grounding device installed in connection with the dextrine reel (already referred to on p. 11) in an eastern plant where an explosion occurred. The film of oil existing between a shaft and its bearing may, and in the opinion of many does, act as an insulation, and thus render the method just described inefficient. When this was explained to the men in the field, many of them decided not to depend upon grounding from the bearings but to install a properly grounded direct copper brush contact to each shaft as recommended by the investigators.

In a number of cases the owners were desirous of having the investigators equip their machines to conform to the ideas advanced, and about 15 machines were so wired. It is of interest to note that no explosion or fire occurred in any machine grounded in this manner, while in one case an outfit not so equipped had two fires.

Second method.—The second method was the one which the investigators generally advocated, and was readily accepted by the mechanics and experienced thresher men, for it provides a double security. All moving parts were connected with each other and to a common wire, thereby destroying any difference of potential existing within the machine. This common wire was thoroughly grounded to relieve the machine of any surplus charge that might accumulate in it. About 10 machines were wired in this manner, consisting of a direct brush contact to the revolving shafts by means of a stiff strip or bar of copper. These machines, although located in parts of the territory where explosions and fires were most frequent, had neither an explosion nor a fire after being so equipped.

Third method.—The third method, that of grounding the moving parts on some heavy metallic part of the frame, was based on the theory that if the difference of potential between parts could be destroyed there would be no tendency for sparking between moving shafts and other metal parts. Several machines were wired in this manner during the season and all finished threshing without experiencing any fires or explosions. Field tests with electrical measuring instruments, however, did not show the complete absence of electricity in these cases, as was found in the other systems of wiring.

BLOWER SYSTEMS.

The possibility of removing the dust from the vicinity of the cylinder by means of a fan or blower located on top of the separator

suggested itself at the beginning of the study. The department, early in 1915, took this matter up with various representative manufacturers with a view to observing the efficiency of such an installation on threshing machines during operating conditions. The investigators collected information pertaining to the efficiency of such installations of this nature as were working in the field.

In one case a machine equipped with a blower system of this kind threshed 27 days in 1914 and 20 days in 1915. During this time only one flash occurred in the dust pipe, but this did not cause a fire.

The blower system consisted of two 15-inch fans mounted on the frame of the separator below the cylinder and a 20-inch suction fan mounted on the top of the separator. These fans were so arranged that the draft passed up and around the cylinder in the direction of the travel of the grain and straw. The opening to the suction fan was 4 inches in width and extended across the separator. In addition to preventing the formation of an explosive mixture of dust and air, this arrangement had an additional value, according to the owner, in that it cleaned the grain during the threshing to such an extent that he was enabled to get a better price for it. The dust collected by this system was blown through a special 10-inch pipe to the straw stack.

In another case a single suction fan was located beyond the cylinder on the opposite side from the main drive belt. In two cases where fire occurred the fan drew the fire out of the machine before any damage was done. The discharge was so located that the fire did not reach the straw pile or the standing grain.

One of the machines operating in a section of the territory where explosions were very frequent had two fans drawing dust from the ends and above the cylinder. In this machine, however, the arrangement was such that there was in the system a large square corner where smut, chaff, and dirt collected, thus defeating the true purpose of the fans.

SPRINKLER SYSTEMS.

In addition to developing an efficient grounding system to remove the static electricity generated during the operation of the machines, and in addition to conducting experiments with blower systems, the investigators endeavored to determine the relative efficiency of types of sprinkler systems and fire extinguishers in use. It was found that there were many different types and patterns of sprinkler systems in general use throughout the territory, but they were all included practically in three different classes:

1. The chemical fire extinguisher.
2. Water with (a) air pressure, (b) steam pump compression.
3. Hose from boiler to separator.

CHEMICAL FIRE EXTINGUISHERS.

The chemical extinguishers in use were arranged to be tripped by hand. They consisted of a tank containing water charged with bicarbonate of soda and a bottle containing sulphuric acid. The tripping device either upset the bottle or liberated a hammer that broke it. The extinguishers in use in the field worked with varying degrees of success.

WATER UNDER PRESSURE.

A number of separators were equipped with water tanks that could be pumped to 100 pounds pressure by a special air pump and were provided with a system of piping from the tank to the separator much the same as was the chemical extinguisher. The results obtained did not appear to be satisfactory, possibly due to the fact that as soon as some of the water had sprayed out the pressure dropped so rapidly that there was not sufficient pressure remaining to be effective. However, a number of machines were saved from total destruction by using this type of extinguisher.

One machine was equipped with a 40-gallon water tank on top of the separator connected to the engine pump which maintained a pressure of 70 pounds. In case of fire, by the pulling of a wire, the pipes from the tank were opened and the water carried to perforated pipes in the separator. As no fires occurred in this machine the tank did not receive a thorough trial.

STEAM LINE FROM BOILER TO SEPARATOR.

Steam or water hose from the engine boiler to the separator was used in many cases with satisfactory results. Its popularity was due to the comparative cheapness of the system (about \$50 to \$75) and also to the success attributed to it by the men who had used it. Best results were obtained when regular steam hose was connected to a point on the boiler below the water line. When a valve was opened at the boiler a pressure of steam and water was obtained which usually was successful in extinguishing the fire.

Where it was difficult to secure steam hose and it was not considered safe to use ordinary rubber hose the line was composed of steam pipe. This made a much more clumsy installation, but it worked successfully when necessary swinging joints were properly installed.

FURTHER EXPERIMENTAL WORK.

In addition to the investigations made in the field based on actual explosions and fires an attempt was made to study in the field or in the laboratory the following:

1. Prevalence and distribution of static electricity in and about the separator.
2. Inflammability of smut dust.
3. Effect of introducing foreign material, accidentally or maliciously, into the separator.

MEASUREMENT OF DISCHARGES OF STATIC ELECTRICITY.

Both steel and wooden separators were tested while threshing both smutty and smut-free wheat and also oats. The common plan of procedure was to establish a good reliable "ground" by driving an iron rod deep into the earth, pouring water around it, and connecting one lead from a galvanometer to this rod. The other lead from the galvanometer was loose and was touched in turn to cylinder shaft, frame, blower, and all moving parts.

On all machines tested strong discharges were obtained from almost every part of the machine to the ground, but in many cases the strongest appeared to be from the front wheels to the ground. Strong discharges were also obtained between the cylinder shaft and concaves, and slight ones between a moving and a stationary metallic part, and between any two moving parts. The galvanometer used in the tests was the ordinary two-coil instrument showing deflection and direction but not magnitude of the current.

FIELD EXPERIMENTS.

At the close of the threshing season three day tests were run on a donated separator in the field in northern Idaho, under as nearly actual threshing conditions as could be secured at that time. As it was impossible to obtain unthreshed smutty wheat, it was necessary to make use of straw mixed with loose smut secured from a local mill. At the time of the tests the temperature was at least 50 degrees below that prevailing during the threshing season, and the weather was unusually damp. Because of the conditions existing, the results of these tests can not be considered conclusive, but they tend to confirm the deductions made from the investigations in the field during the threshing season.

STATIC ELECTRICITY AND ELECTRIFICATION OF SMUT DUST.

The experimental work carried on during the investigations proved conclusively that, under favorable atmospheric conditions, static electricity is present on all types of machines. In the Pacific Northwest humidity conditions during the entire threshing season are favorable for the production of static electricity. The air as a rule is very hot and dry, with the humidity on certain days as low as 7 per cent, the average being about 17 per cent for the middle of the day.

It appears that the largest discharges of static electricity were obtained from the steel machines. Larger deflections were also obtained in threshing wheat than in threshing oats. The fires and explosions occur as a rule while fall wheat is being threshed and very rarely occur during the threshing of spring wheat. The discharge from the machines while smutty wheat is being threshed is more noticeable than when clean wheat is going through the machine. Fall wheat as a rule contains much more smut than does spring wheat. The theory that the small particles of smut easily become electrified when the kernels are broken up by the cylinder teeth and that each particle becomes charged with static electricity has been advanced as a possible explanation of the fact that the largest discharges seem to occur when smutty wheat is being threshed. The theory is tentative and can be proved only by experimental work to determine in what manner the static electricity is generated.

INFLAMMABILITY OF SMUT DUST.

In addition to the experimental work carried on in the field during the progress of the investigations, a series of laboratory experiments to determine the inflammability of smut dust was conducted by J. C. Woodson, assistant agricultural engineer, at the University of Idaho. This work was done in the laboratories of the Department of Physics, and advice and assistance were obtained from Prof. Angell.

The laboratory experiments were by no means conclusive and not so extensive as work already planned for the future, but were merely preliminary in nature. However, they were sufficient to indicate that smut dust is highly inflammable and can be ignited by an electrostatic spark.

FOREIGN MATERIAL ENTERING MACHINE.

In many cases the investigations indicate that foreign material consisting of gravel, flint, metal, etc., entering the machines and the rubbing and friction of cylinder teeth produced sparks which may possibly have ignited the dust. In one case both cylinder and concave teeth were found bent forward after the explosion and showed signs of rubbing.

In some cases the explosions occurred during the clean-up, which suggested to the owner the possibility of sparks being produced by foreign material entering the machine. This matter can be decided only by experimental work to establish clearly the relation between the suspended dust cloud and sparks produced in this manner. This cause has been assigned to dust explosions in grain mills and industrial plants, and is at the present time receiving attention.

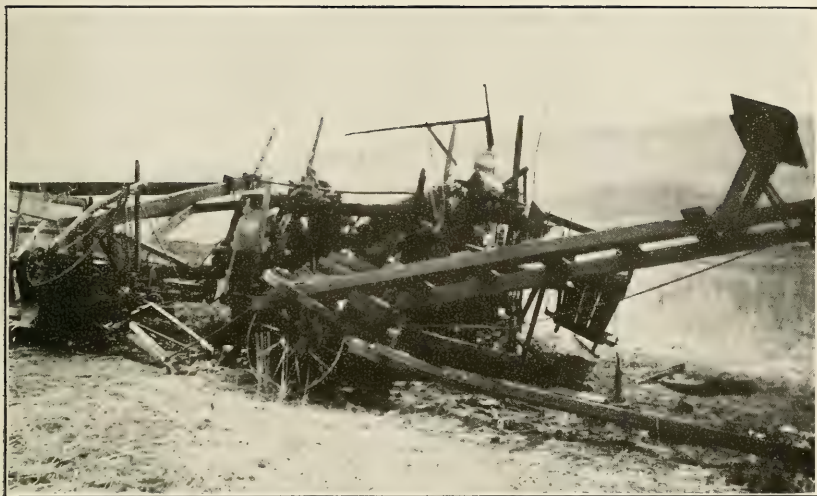


FIG. 1.—COMBINE MACHINE AFTER SMUT EXPLOSION AND FIRE, IN EASTERN WASHINGTON.

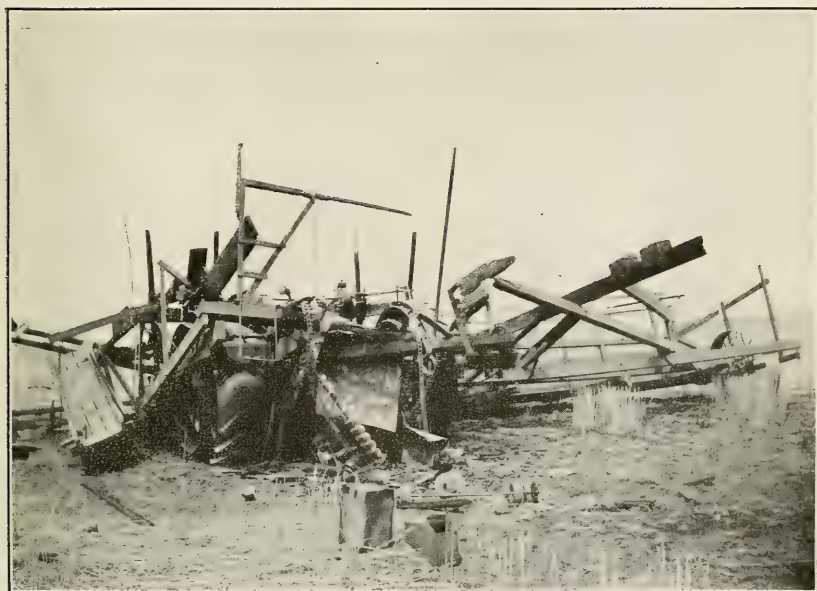


FIG. 2.—ANOTHER VIEW OF SAME MACHINE.

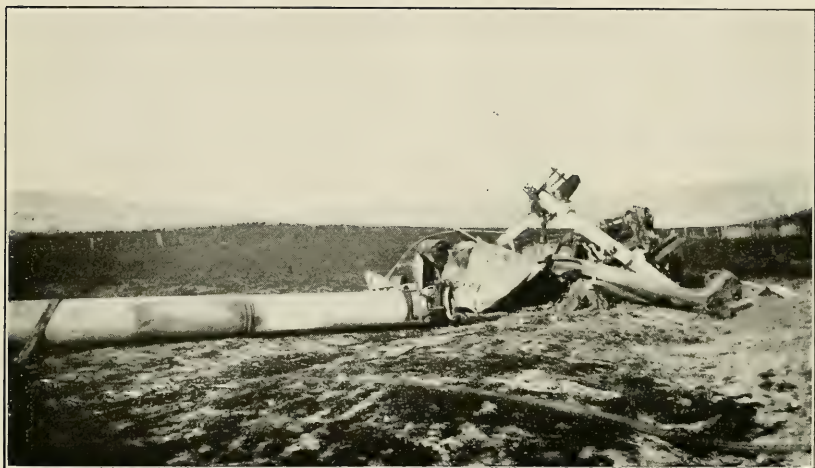


FIG. 1.—REMAINS OF THRESHING OUTFIT AFTER SMUT EXPLOSION AND FIRE, NEAR PULLMAN, WASH.



FIG. 2.—PILE OF 750 SACKS (1,875 BUSHELS) OF WHEAT DESTROYED BY FIRE FROM EXPLOSION IN ABOVE MACHINE.

EXPERIMENTS WITH MATCHES AND ACIDS.

Experiments also were conducted to determine the resulting action of various acids on matches. A current opinion existed that many grain fires in the fields were caused in this manner. Matches were tied about the neck of a small vial containing sulphuric acid and also one containing nitric acid. A cork about one-eighth of an inch thick was placed in the mouth, and the bottles were inverted, allowing the acids to eat through the corks and come in contact with the match heads. These acids were tried with eight different varieties of matches, but failed to ignite the matches in a single case. The acids experienced no difficulty in eating out the corks, the nitric acid doing so in 40 to 60 minutes and the sulphuric acid requiring 6 to 10 hours.

NATURE OF DUST EXPLOSIONS.

THEORY OF DUST EXPLOSIONS.

The theory of dust explosions, although not entirely new, has not been understood clearly by a number of people, who are, therefore, at a loss to know in what manner these explosions originate and the circumstances necessary for their occurrence. That dust itself can be made to explode without the presence of inflammable gases has seemed incredible.

Experimental work has shown that the dust produced during the handling of grain can be ignited under certain conditions, and will propagate a flame with explosive violence. It must not be concluded that grain dusts will ignite spontaneously. On the contrary there must be some outside source of heat. This source may be very small, as a heated coil of wire or an electric spark as used in the experimental work, or it may be larger, as a flame which may have a lower temperature but a larger heating surface.

The following illustration may simplify the explanation of the nature of dust explosions. We might try for some time to burn a block of wood with a lighted match. If we take a knife and chip the block the shavings will ignite more quickly. We might make excelsior and find it would ignite still more rapidly, and then continue by gradual reduction to a degree of fineness until dust is produced, when it is found that the mass will burn rapidly when in suspension and diffused in the air. The rate of burning is so rapid that a violent explosion may result.

Many theories have been advanced as to the conditions under which dust explosions are produced and the amount of dust in suspension necessary to propagate the explosion. The predominating factors which determine the inflammability of a dust and the action of a dust explosion have not been definitely determined. It is generally

agreed, however, that the dust must be fine and dry and in a state of suspension in the atmosphere, so that upon being brought in contact with sufficient heat or flame an ignition is caused. It generally is conceded that there must be a proper proportion in diffusion in order for the explosive mixture of dust and air to ignite with sufficient force to propagate an explosion.

The conditions under which these thresher fires and explosions occur appear somewhat similar to those with other cereal dusts. During the threshing process the smut, which is a form of very fine, dry dust, is thrown into suspension in the air and forms a dangerously explosive mixture, which readily would produce an explosion or fire if ignited. The mixture of smut dust and air may have limits of explosibility, and it is quite possible at times to have too much dust present, and at other times not sufficient, for an ignition. For this reason explosions may occur at a given time and under certain conditions and not occur at other times or under different conditions.

AMOUNT OF DUST REQUIRED FOR EXPLOSION.

Explosions have been produced at the Pittsburgh Testing Station of the United States Bureau of Mines when there was only 0.032 ounce of coal dust suspended in each cubic foot of air, or 1 pound in 500 cubic feet. In order to produce complete combustion it takes all of the oxygen in 1 cubic foot of air to burn completely 0.12 ounce of the coal dust used.¹ Preliminary experiments have shown that smut dust is highly inflammable, and also that many of the cereal dusts have relatively a lower ignition temperature and produce higher pressures than coal dusts. It might be concluded that the explosive limits of cereal dusts would be lower than those of the coal dusts.

In some of the thresher explosions at least two distinct reports were heard; the first being sharp and quick and the second resembling a loud roar and lasting longer than the first and accompanied by more flame. An explosive mixture consisting of sufficient quantity of smut dust in suspension, ignited by sufficient source, would no doubt cause the sharp report usually heard first. This original ignition, possibly only an inflammation, might produce sufficient concussion to shake the dust that had settled on various parts of the separator into suspension in the air, thus forming an additional explosive mixture. The heat or flame from the first small puff or inflammation would cause an ignition of this newly formed mixture, and the explosion would propagate through the entire dust zone. This may serve to explain the loud rumbling sound sometimes heard, accompanied by a large body of flame causing extensive damage.

¹ U. S. Dept. Interior, Bureau of Mines. Miners' Circular No. 3, Coal-Dust Explosions, (1911), p. 7. Geo. S. Rice.

METHODS DEVELOPED FOR PREVENTING EXPLOSIONS OR EXTINGUISHING FIRES.

GROUNDING THE SEPARATOR.

As a result of the investigations carried on by the department during the past season, it is believed that a complete system of electrical connection from all of the moving parts to a common wire, and a thorough grounding of this common wire, will prevent a large percentage of the fires that are due to the presence of static electricity and an explosive mixture of smut dust and air. There are, of course, several ways in which this wiring may be installed, and the system will vary somewhat with the type of machine.

One arrangement that is considered by the engineers of the department to provide as nearly complete protection from ignition by static electricity as any other is illustrated in Plate VIII. An inspection of this illustration will show that the common wire or conductor, A, is grounded through a rod, B, which should be driven at least 3 feet into the ground and kept well moistened. There is a connection, C, to this conductor from the shaft of the cylinder through the copper brush D. This brush is in contact with the shaft itself and not with the bearing. This construction is used to avoid any possibility of insulation due to the film of oil between the shaft and the bearing. The shakers are connected to the lead E. The lead F, which extends over the entire sieve, connects that piece to the common wire. The lead G connects the metal casing of the stacker fan to the wire A. The investigations in the field indicate that the moving parts just described are the ones on which static electricity is likely to be generated. These investigations also show that there were occasional collections of static electricity on the metal casing. For this reason that connection has been made. The common lead and its main branches are of No. 14 bare copper wire. The connections, particularly to the moving points, should be of flexible insulated wire coiled a sufficient number of turns to permit full flexibility. The wires should be attached to the framework of wooden machines by staples, which should be of the insulated type, or there should be a cushion of rubber or other material between the staple and the wire, as otherwise the wire is likely to snap at that point and break the circuit.

SUCTION FAN.

As it is necessary, in order for an explosion to occur, to have present in the separator an explosive mixture of dust and air, the arrangement illustrated in Plate IX is suggested as a means for preventing the formation of such an explosive mixture. The arrangement consists of attaching to the top of the separator, and near the cylinder, a suction fan, A. This fan exhausts from above the cylin-

der as shown at B, and also from beneath the fan as shown at C, there being another connection on the opposite side of the fan from C.

The method of installing the fan necessarily will vary with the type of separator. The object is to remove the dust from near the cylinder. The fan should be arranged to accomplish this.

There is no way of demonstrating by experiment that either of these methods actually prevents explosions, but the fact that no such occurrences took place in the case of separators properly equipped with either one of these devices, while explosions and fires were constantly occurring in machines located near them and not so equipped, warrants the belief that the devices proved effective in preventing explosions and consequent fires.

AUTOMATIC FIRE EXTINGUISHER.

Experiments conducted in the field during the threshing season, and since that time on the Arlington Experimental Farm at Arlington, Va., show that, under ordinary conditions, it is very difficult to secure a fire in a separator by the introduction of matches or other foreign materials. This has been particularly the case in experiments conducted on the Arlington Experimental Farm, in which, owing to the lack of smut dust and proper atmospheric conditions, it was impossible to secure an explosive mixture in the separator. In order to set fire to the separator in these experiments, it was necessary to introduce a flame and, to secure positive results, use was made of waste and rags soaked in gasoline and ignited by a flame from the outside. Bundles of matches fed in with the straw did not cause a fire.

However, since there is a possibility that fire will be caused under certain conditions by the entrance into the separator of foreign materials, and since it was impossible to prove positively that either grounding the separator or the use of the suction fan was a sure preventive of fires, it was decided to design an automatic fire extinguisher that would afford protection irrespective of the cause of the fire or explosion. Such a device is shown in Plates X and XI. It consists of the following parts: Tank A mounted on top of the separator; within the tank a bottle, C, containing sulphuric acid; a discharge pipe, H; a tripping mechanism composed of operating levers G and main tripping lever L; a trigger, N; discharge nozzles, I; and fuses, F, mounted in a wire line. In the discharge line between the tank and the separator may be mounted a three-way valve, P, from which there may be led, as at R, a hose connection for extinguishing outside fires. The tank is filled with water containing soda. The operation of the device is as follows:

The presence of sufficient heat within the separator will melt one of the fuses F. This breaks the wire line, releasing the trigger which

frees the tripping mechanism, causing a hammer within the tank to strike a blow sufficient to break the bottle. The discharge of the sulphuric acid into the water containing soda causes the formation of carbon dioxide, which generates sufficient pressure to force the water through the discharge pipe and the nozzles to all the crevices of the separator.

This extinguisher was designed in the Office of Public Roads and Rural Engineering, after the completion of the work in the field, by Elmer Johnson, assistant mechanical engineer, and J. C. Woodson, assistant agricultural engineer. A full-sized working model was constructed and has been tried out in the explosion galleries of the Bureau of Mines at Pittsburgh, Pa., and since that time on four different types of separators at the Arlington Experimental Farm. A total of 27 tests with this extinguisher have been made, and in no case did it fail to operate automatically and properly and to extinguish the fire before any damage was done.

The locations of the fuses F shown in the sketch are those suitable for the particular machine shown in the drawing. The locations, however, will vary with each machine, and must be selected so that the fuses are sure to be reached by the flame or the heat, but not so placed that the wire connecting them is likely to be broken by the straw or by the moving parts of the separator.

The location of the nozzles depends upon the construction of the machine, but the following points should be observed:

Locate one nozzle directly above the cylinder, if possible; if not, place it so that the beater will help diffuse the spray from that nozzle.

Run the pipe line along underneath the roof of the separator, with the nozzles pointing downward.

Install a sufficient number of nozzles along this line, and so locate them that every chamber in the separator is thoroughly served by a nozzle.

Particular pains should be taken to serve dead air spaces, as it is in these that dust is likely to accumulate.

As the stacker end of the machine is less likely to contain any closed chambers, it is probable that, in most types of machines, the nozzles at this end may be 30 inches or more apart.

The last nozzle along the pipe line and within the separator should be just above the end of the shakers.

One nozzle may be located in the wind stacker by means of a flexible connection from the pipe line.

The tripping mechanism of this extinguisher is so arranged that it may be released by hand, and also arranged so that it can be locked while on the road. Two pounds pull is sufficient to release it, but it has proved to be sufficiently rigid to withstand the jar and

vibration due to the threshing. In no case has it released itself prematurely.

It has been suggested that, when not in use on the separator, this device can be mounted on running gears and used for general fire protection about the farm.

A special nozzle was designed for use with this extinguisher. It is shown in detail in figures 2, Plate XI.

Large-scale drawings of these three devices are on file in the Office of Public Roads and Rural Engineering, and may be secured on application by manufacturers, owners, or operators of threshing outfits who seriously contemplate the installation of one or more of them.

SPECIAL ACKNOWLEDGMENTS.

In connection with carrying on the work described in this bulletin, special acknowledgment is due to Dr. H. H. Brown, assistant chemist, Bureau of Chemistry, and Elmer Johnson, assistant mechanical engineer, Office of Public Roads and Rural Engineering, for assistance rendered in conducting experiments in the laboratory to determine the inflammability of smut dust, in designing the apparatus described herein, and in conducting tests at the Bureau of Mines' galleries at Pittsburgh, Pa., and with grain separators at Arlington Experimental Farm.

Acknowledgment is also due to the Grain Standardization Laboratory, Portland, Oreg., for assistance in investigations and in collection of grain samples; to the Bureau of Plant Industry for assistance in experimental work at the Arlington Farm; and to the Bureau of Mines for use of the explosion galleries and laboratories at Pittsburgh, Pa.

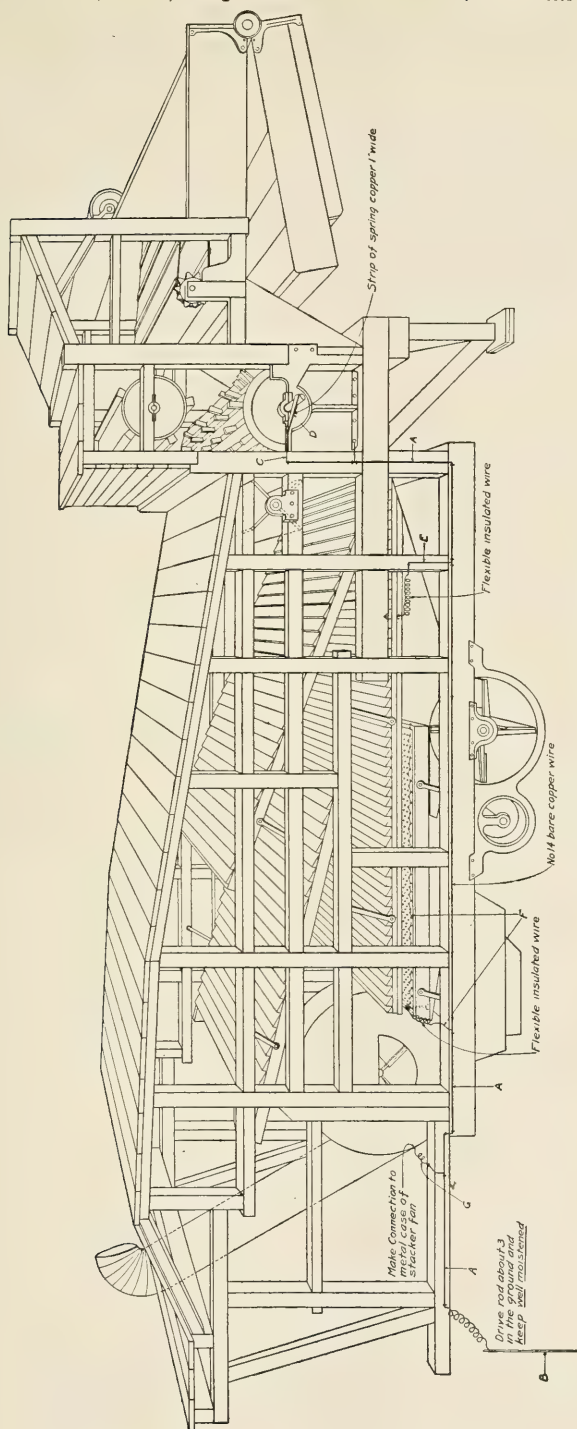
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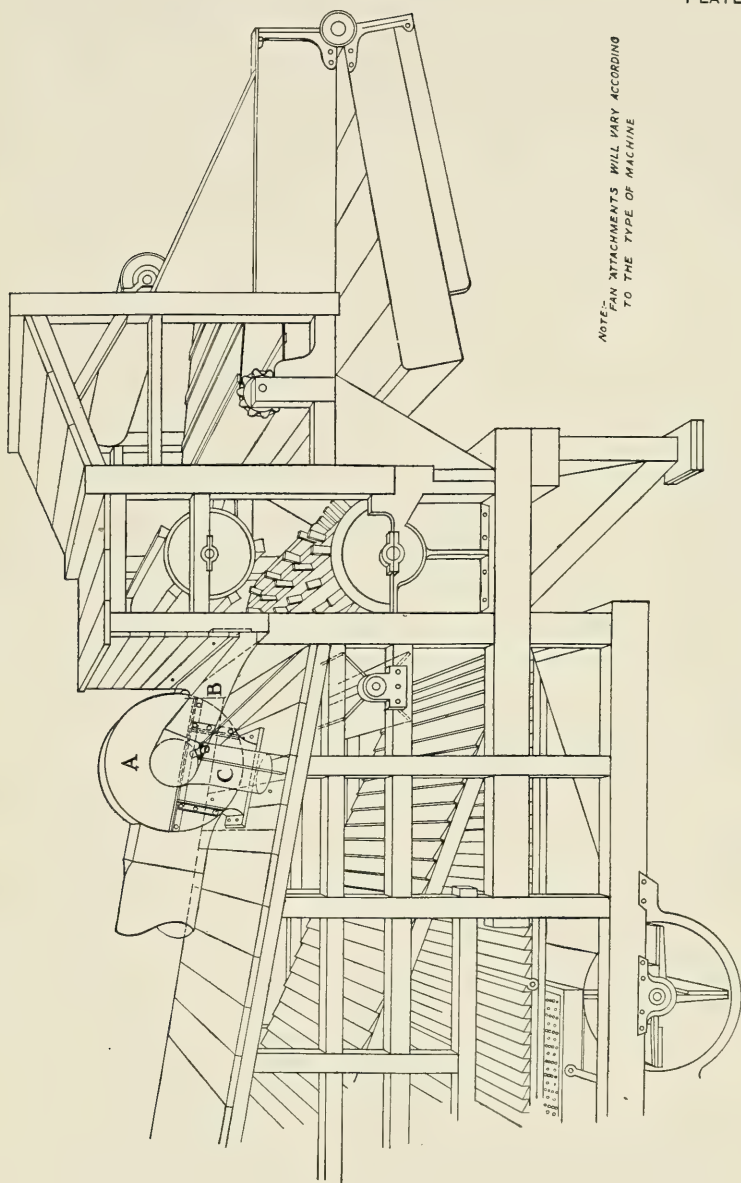
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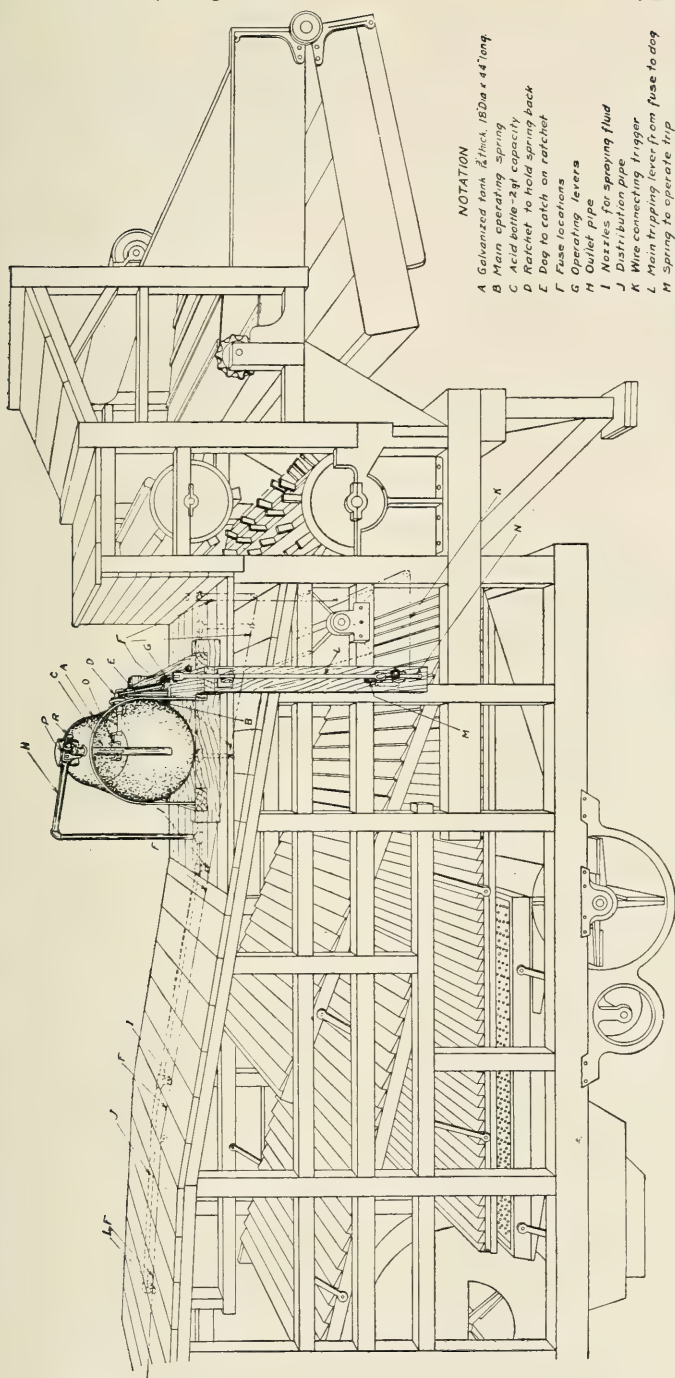
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WIRING SYSTEM FOR GRAIN SEPARATORS.



SUCTION FAN INSTALLATION.



NOTATION

- A Galvanized tank $\frac{1}{2}$ " thick, 18" dia. x 44" long
- B Main operating spring
- C Acid bottle - 2 gal capacity
- D Ratchet to hold spring back
- E Dog to catch on ratchet
- F Fuse locations
- G Operating levers
- H Outlet pipe
- I Nozzles for spraying fluid
- J Distribution pipe
- K Wire connecting trigger
- L Main tripping lever from fuse to dog
- M Spring to operate trip
- N Trigger to hold down trip
- O Hammer for breaking bottle
- P Three way valve
- R Long pipe nipple for hose connection

AUTOMATIC FIRE EXTINGUISHER.

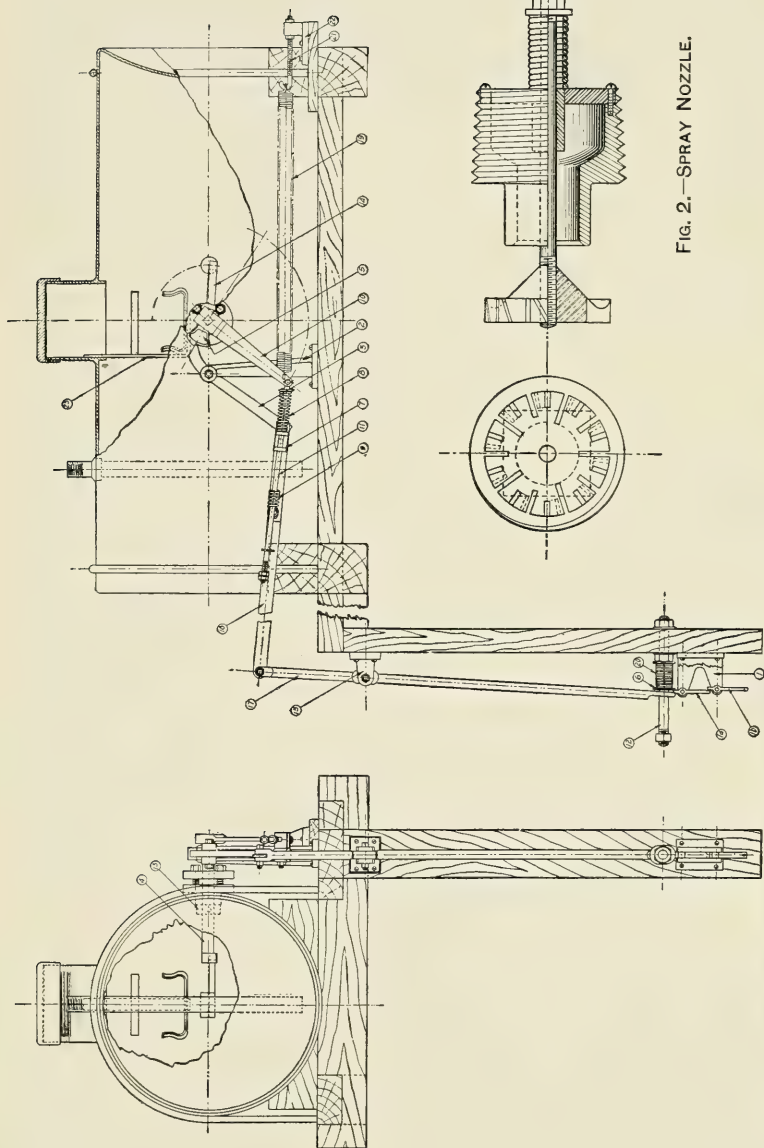


FIG. 2.—SPRAY NOZZLE.

FIG. 1.—DETAIL OF AUTOMATIC FIRE EXTINGUISHER.

UNITED STATES DEPARTMENT OF AGRICULTURE



BULLETIN No. 380

Contribution from the Bureau of Plant Industry
WM. A. TAYLOR, Chief



Washington, D. C.

PROFESSIONAL PAPER

January 15, 1917

ENDOTHIA PARASITICA AND RELATED SPECIES.

By C. L. SHEAR, *Pathologist*, and NEIL E. STEVENS,¹ *Pathologist, Fruit-Disease Investigations*, and RUBY J. TILLER, *Scientific Assistant, Office of Investigations in Forest Pathology*.

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TAXONOMY.

INTRODUCTION.

The discovery of a serious canker of the chestnut in the New York Zoological Park in 1904, by Merkel (49),² first attracted the attention of pathologists and foresters to what has proved to be one of the most serious epidemics of a plant disease ever known in this country.

The fungus which was found associated with these cankers (Pl. I and Pl. II, fig. 1) and soon demonstrated experimentally to be their cause was described by Murrill (57) in 1906 as a new species of *Diaporthe* (*D. parasitica*). Search for the fungus in other places in New York and vicinity soon showed that it was already established and apparently rapidly spreading. Investigations which have been continued and extended from year to year have shown

¹ Formerly Pathologist, Office of Investigations in Forest Pathology.

² Serial numbers in parentheses refer to "Literature cited," at the end of the bulletin.

NOTE.—This bulletin is of value to botanists, especially plant pathologists and mycologists, and to all persons who are interested in the study of chestnut blight.

conclusively that the disease is spreading very rapidly, especially west and south from New York and also north and east.

The exact identity and relationships of the fungus causing the disease and the origin of the epidemic soon became the subject of study by various mycologists and pathologists. Different explanations were offered for the sudden appearance and behavior of the disease, one view being that the fungus was probably a foreign parasite which had been introduced; another, that the organism was probably a native species which had recently attracted attention, chiefly by reason of the weakened condition of the chestnut trees due to abnormal climatic or other conditions.

In attacking the problem of the origin of the parasite and its possible control, it was evidently necessary to secure all the information possible in regard to its life history, identity, distribution, and relationships. The senior writer in an unpublished paper prepared in 1908 pointed out the close relationship and possible identity of *Diaporthe parasitica* with certain species of *Endothia*. Clinton (16) and Farlow (28) soon after also made the same suggestion. Two species of *Endothia* had already been described from this country by Schweinitz (74) under the old generic name, *Sphaeria*. These, however, had in recent years been regarded as a single species and referred to *Endothia gyrosa* (Schw.). Owing to a lack of knowledge of the types of these two species and for want of good specimens showing ascospores, it was difficult to determine what species of *Endothia* were indigenous in the eastern United States. Since it had been suggested that *Diaporthe parasitica* was either identical with one of Schweinitz's species or a mere variety of it, the present writers undertook a thorough study of the genus *Endothia* in its taxonomic, ecological, and pathological relations. It was first necessary to determine the identity of the two species already described by Schweinitz from America and also to learn their distribution and host relations. As one or both of Schweinitz's species were reported to occur in southern Europe on chestnut, it was important to obtain exact knowledge in regard to the identity and relationships of the European species. The senior writer spent several months in Europe collecting material of *Endothia* in the field and studying herbarium specimens of types and authentic collections of Schweinitz and other authors. Material was also acquired by collection and exchange with pathologists and mycologists in nearly every region of the world in which *Endothia* was known to occur. Comparative cultural studies were made of all the living material secured, as well as inoculation experiments on various hosts. The recent discovery of the typical chestnut-blight parasite, *Endothia parasitica*, by Meyer (27, 76, 78), in China and Japan and the failure to find in Europe or America any native form which would produce the disease appear to settle beyond question its foreign origin.

The present paper presents the results of several years' field and laboratory study of the species of *Endothia*. This includes the study of practically all the herbarium material of this genus preserved in the principal herbaria of Europe and America; also field and laboratory studies of over 600 new collections from various localities and hosts in America, Europe, and Asia. Over 4,000 cultures have been studied and about the same number of inoculations made. These studies include the systematic relations of the species of *Endothia* and their physiological behavior on various culture media and under various conditions of light, moisture, and temperature; also inoculation experiments with the various species on various hosts.

The writers wish to record here their grateful acknowledgment and thanks for opportunities to examine specimens and for assistance rendered by various mycologists and pathologists and directors and curators of botanical gardens and museums, especially the following: Prof. O. Comes, Naples; Prof. Romualdo Pirota, Prof. Giuseppi Cuboni, and Drs. E. Pantanelli and L. Petri, Rome; Prof. P. Baccarini, Florence; Prof. P. A. Saccardo, Padua; Dr. G. Briosi, Pavia; Dr. J. Briquet, Delessert Herbarium, Geneva; M. G. Beauverd, Boissier Herbarium, Geneva; Prof. L. Jost, Strasburg; Prof. W. Pfeffer, Leipzig; Dr. G. Lindau, Berlin; Dr. J. W. C. Goethart, Leiden; Prof. H. O. Juel, Upsala; Dr. P. Hariot, Paris; Sir David Prain, Kew; Dr. A. B. Rendle, British Museum; Prof. I. B. Balfour, Edinburgh; Prof. T. Petch, Peredeniya, Ceylon; Dr. C. Spegazzini, La Plata, Argentina; Dr. W. G. Farlow, Harvard University; Dr. W. A. Merrill, New York Botanical Garden; Mr. Stewardson Brown, Philadelphia Academy of Science; Dr. G. T. Moore, St. Louis Botanical Garden; Prof. E. Bethel, Denver, and Drs. G. P. Clinton, P. J. Anderson, and F. D. Heald. The writers have also received specimens and cultures from numerous other colleagues which have been of great assistance and are duly appreciated.

THE GENUS *ENDOTHIA*.

The genus *Endothia* was established by Elias Fries in 1849 (33, pp. 385-386), as follows:

(X. *Endothia*. Fr.*)

*Colore rubro fulvove, habitu Tuberculariae, peritheciis cellulosis difformibus pallidis, ascis diffuentibus, facile distinctum genus, nobis exoticum, sed jam in Europa australi obvium v. c. *Sph. gyrosa* Schw.—et subgenus, tuberculo uniloculari, sistit *S. Tubercularia* Dec. Omnium horum generum characteres proxime plenius exhibeamus, examinatis multis speciebus exoticis.

The description of the genus transcribed here was published as a footnote in the work cited and was evidently based on the specimens contained in Fries's herbarium at the time the book was written.

Fries (31, p. 73) had at that time, according to his own statement, authentic specimens of *Sphaeria gyrosa* sent him by Schweinitz and also the specimens collected by Guepin and Levieux in France, which he identified as this species. In Fries's herbarium at Upsala at present are found specimens of true *S. gyrosa* Schw. with Schweinitz's autograph label, but no specimens of *S. gyrosa* could be found attributed to Guepin or Levieux. There is a small packet marked "*Sph. gyrosa*," apparently in Fries's handwriting, but there seems to have been some confusion in the labeling or mounting of this specimen, as a small stroma of *Hypoxyylon annulatum* which does not look at all like *Endothia* is included. The other piece consists of an irregular pycnidial stroma which may be the southern European specimens referred to in the description quoted. Fries's identification of this European material as *E. gyrosa* was apparently based chiefly upon its superficial resemblance to the pycnidial stromata of Schweinitz's American specimens. The senior writer has seen and made a careful microscopic examination of a specimen collected by Guepin in France and preserved in De Notaris's herbarium at Rome. It is labeled "*Sphaeria gyrosa* Fries, Guepin, Angers." The specific name "*gyrosa*" has been crossed out by De Notaris and "*radicalis* Schw." written above it and the date "April, 1845," added. This appears to be a part of the same collection that Guepin sent to Fries, as the specimen agrees well with Fries's description and consists chiefly of pycnidial stromata which are rather larger than is usual for *Sphaeria radicalis* and show considerable superficial resemblance to the stromata of *Sphaeria gyrosa* Schw. A thorough examination of this specimen, however, reveals a few perithecia and ascospores, which leave no doubt that it is *S. radicalis* of Schweinitz, as indicated by De Notaris on the label. What the plant sent Fries by Levieux was is unknown, as no specimen so labeled could be found in Fries's herbarium. It appears from all the evidence at hand that Fries was mistaken in his identification of the material from Levieux and Guepin, as no specimens of the true *Sphaeria gyrosa* Schw. have yet been seen from Europe.

There seems to be no doubt, however, that Fries intended the true *Sphaeria gyrosa* Schw. to represent the type of his genus *Endothia*, as he had a part of Schweinitz's original collection at the time and never definitely placed any other species in the genus; hence, *Sphaeria gyrosa* Schw. should be adopted as the nomenclatorial type of the genus. It is clear from Fries's writings and specimens that he knew *Sphaeria radicalis* Schw., as he had American specimens from Schweinitz as well as European collections at the time he founded this genus. He did not, however, apparently regard it as congeneric with *S. gyrosa*. His specimens of *S. radicalis* show

the typical perithecia with necks, whereas no perithecia have been found in any of Schweinitz's specimens of *S. gyrosa* examined by the writers. Fries, in common with Schweinitz, regarded the pycnidial cavities of *S. gyrosa* as perithecia. When the pycnidia of *S. gyrosa* are mistaken for perithecia and compared with the real perithecia of *S. radicalis* the differences appear marked. It was therefore quite as natural for Fries to place the two species in different genera as it had been for Schweinitz to place them in different tribes of the genus *Sphaeria*. Fries's mistake in describing as perithecia the pycnidial cavities in the stroma of *S. gyrosa* explains his reference to the asci as "ascis diffluentibus." Believing that he had perithecia but finding no asci, he interpreted this as indicating that they had disappeared.

According to the plan of accepting only names originally applied to the ascospore stage, this name would be invalid, as proposed by Fries, and would be attributed to De Notaris, who placed the perithecial form of *Sphaeria radicalis* Schw. in the genus and described the ascospores. There is not the slightest question, however, in regard to the identity of the different stages of this fungus and their genetic connection, and the name *Endothia* has been almost invariably applied to these two species in both stages.

SYNONYMY.

There are only two true generic synonyms of *Endothia*: *Endothiella* Saccardo, 1906 (71, p. 278) and *Calopactis* H. and P. Sydow, 1913 (81, p. 82). *Endothiella* was based on *Endothiella gyrosa* Sacc., which, according to authentic specimens from Saccardo, is undoubtedly the pycnidial form of *Endothia fluens* as found in Italy. *Calopactis* was based on *C. singularis*, the pycnidial condition of *Endothia singularis* (H. and P. Syd.) S. and S. Ascospore cultures of this have not yet produced any pycnidia, but the proof of the genetic connection of the two stages appears rather conclusive from the occurrence of pycnidia and perithecia in the same stroma, as shown in Plate XII. Perithecial stromata and ascospores were also found in the specimen of the Sydow exsiccati in the Pathological and Mycological Collections of the Bureau of Plant Industry.

Von Höhnelt (43, p. 1479-1481) considers *Cryphonectria* Sacc. as a synonym of *Endothia*, taking *C. gyrosa* (B. and Br.) as the type of that genus because it is the first species listed by Saccardo in connection with his description of the genus. Saccardo, however, had previously established *Cryphonectria* as a subgenus, with *C. abscondita* as the type, which is not an *Endothia*. *Valsonectria* is also considered by Von Höhnelt a synonym of *Endothia*, but apparently he had not compared specimens of Spegazzini's fungus, which is found upon examination of the type species to be separate from *Endothia*. The

Tulasnes (83, p. 87-89) do not appear to have regarded *Endothia* as distinct from *Melogramma*, to which they referred *E. gyrosa*. The type of *Melogramma*, however, is *M. melogramma* (Bull.), which has a somewhat similar stroma, but the ascospores are 3-septate and dark colored and the perithecia not separable from the stroma, while the pycnosporos are long, slender, and curved.

STUDY OF EARLY COLLECTIONS AND TYPES.

There has always been more or less uncertainty in regard to the identity of the older species of this genus of fungi. In order to get more light on this subject, a thorough study of all the available material in the way of literature, type specimens, and manuscripts was made. The first species to be described in this country was *Sphaeria gyrosa* Schw. This was collected by Schweinitz at Salem, N. C., and published in 1822 (72, p. 3).¹ Two hosts were given in the original description, *Fagus* and *Juglans*.

As Schweinitz's description was prepared before the advent of careful microscopical studies and spore measurements, it is impossible to identify the organism satisfactorily from the original description. It was, therefore, important, if possible, to locate the type specimens upon which the description was based. Schweinitz's herbarium was left at his death, in 1834, to the Philadelphia Academy of Science. His specimens of fungi at the time they were transferred to the academy were contained in small, folded paper packets, as shown in Plates V and VI. These packets were then inclosed in other heavy paper wrappers, folded to small quarto size, and three or four of these large packets, each bearing a manuscript list of the species contained, were then inclosed in quarto pasteboard covers, tied with tape. The individual species packets were labeled in Schweinitz's handwriting, with the name of the species and the locality of the collection, as shown in Plate V, figure 2.

These species packets frequently bore the names of several localities, but usually two, Salem [N. C.] and Bethlehem [Pa.], as most of his collecting was done at these places. This fact, in addition to the evidence afforded by the specimens in the packets, clearly indicates Schweinitz's method of handling his specimens.

Frequently some of the specimens in a packet show the remains of a gummed strip. This will be noticed in Plate III, which indicates

¹ 24. *Sphaeria gyrosa* Sz.

S. subperipherica minor gregaria subconfluens aurantio miniata, sphaerulis gyrosis farctis demum prominulis pulverulentis, stromate lutescenta.

In cortice nondum corrupto etiam vivo Fagorum et Juglandum. Junior planiuscula, ubi adolevit sistit corpus subrotundum, tuberculis minimis et magoribus asperum et gyrosum. Sphaerulae farctae, teretes, supra gyrosae, paucae, radiatim divergentes a superficie ad centrum fere stromatis continuantur, primum sublates, demum prominulae, cortice pulverulento; ipsum tamen centrum farinacea carne componitur. Gelatina asciphora albet. Ostiola indistincta.—Transitum facit ad Sphaerias septimae divisionis.

that at one time the specimen was apparently attached to a sheet by a gummed paper strip. This seems to have been the way in which Schweinitz originally mounted his specimens, but later, apparently, he changed to the plan of putting them in paper packets and removed those which had been attached to sheets. It is clear from an examination of the specimens still found in some of the original packets that two or more different hosts were sometimes included. In some cases as many as four or five different collections appear to have been placed in the same packet and each new locality added on the outside. This method of keeping specimens makes it rather difficult in some cases to determine which belongs to the first collection. In the case of *Sphaeria gyrosa* but two localities are indicated on the packet, Salem and New England. (See Pl. VI, fig. 2.)

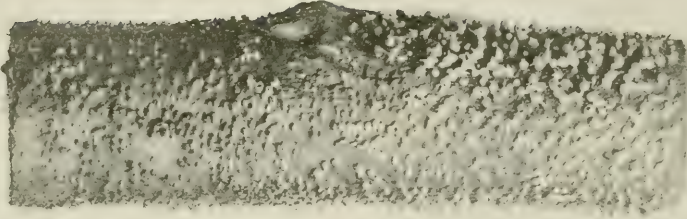
The difficulties in determining the true type specimen of any species would have been sufficiently great if the collection had been preserved as it was left by Schweinitz. The matter is, however, further complicated by the later handling and rearrangement of the collection. Some time after Schweinitz's death (the exact date the writers have been unable to determine) his collection of fungi was more or less completely rearranged and mounted. The greater part of this work was evidently done by Dr. Ezra Michener. Dr. Michener was a lifelong resident of Chester County, Pa. He early became interested in botany, and in 1840 was elected a correspondent of the Philadelphia Academy of Natural Science. He paid special attention to the collection and study of fungi and corresponded and exchanged with various mycologists, especially Curtis and Ravenel. He left a large collection of fungi, which the writers have recently had the privilege of examining. Among his specimens are found many labeled "Ex. Herb. Schw.", which are undoubtedly part of Schweinitz's original collections at the Philadelphia Academy. These specimens, as well as all of Michener's fungi, are mounted in exactly the same manner as the mounted portion of Schweinitz's collection at the Philadelphia Academy. The mounting paper, the specimen slips, the arrangement, manner of attachment, and the handwriting on the labels are identical, as will be readily perceived by comparing the illustrations from photographs of sheets from both herbaria. It is, therefore, clear that the mounted collection of Schweinitz's herbarium was prepared by Dr. Michener. He evidently took from Schweinitz's original paper packets what appeared to him to be the best or most typical specimen of the species in the packet and attached it with glue to a square slip of paper, as shown in Plate III. Where there was but little material in the original packet it was all mounted in this manner. In case there were several pieces in the original packet he used his own discretion in making the selection of the part to be mounted and the part to be left.

When there were included in the original packet specimens from different hosts or different localities, in some cases representing different species, it would have been difficult, if not impossible, to determine which was the original material from which Schweinitz's description was made. At the same time, Dr. Michener, in case the specimen was not too scanty, evidently took a small portion of it for his own herbarium. Michener's catalogue of his herbarium lists *Sphaeria gyrosa* Schw. Consulting his collection it is found that No. 1431, the number of Schweinitz's specimen, is missing. Pin holes in the mounting sheet, however, show that the specimen which was once there has been removed. As perhaps throwing some light on the possible location of this specimen, it may be said that a specimen apparently typical *S. gyrosa*, pycnidial form on beech, labeled by Dr. William Trelease as *Sphaeria gyrosa* from Pennsylvania, was seen in the Boissier Herbarium, Geneva. Dr. Trelease tells the writers that this specimen probably came from Dr. Michener, and as there is no evidence that Dr. Michener or any one else has collected *E. gyrosa* in Pennsylvania there is considerable probability that this specimen represents a portion of Schweinitz's original collection.

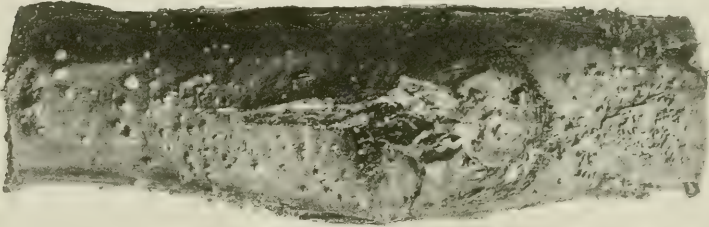
In most cases all of the material in Schweinitz's original species packets was removed and either mounted or distributed. This was the case with *Sphaeria gyrosa*. The original packet of Schweinitz, which was fortunately preserved with all the others, is empty and apparently a part at least of the specimen which it contained is found in the mounted collection as prepared by Michener. This consists of a single piece of bark shown in Plate VI, figure 1. From the evidence the writers have been able to gather from Schweinitz's manuscripts and correspondence, as well as from studies of his writings and specimens in other herbaria, it appears that this specimen is the one indicated on the original packet and also by Schweinitz (74, p. 206) as having been collected in New England and sent to him by Torrey. This, as shown by his correspondence, was after he had left North Carolina. The bark upon which the fungus grew is clearly not *Fagus*, *Juglans*, or *Quercus*, the hosts originally given for *S. gyrosa*, but apparently *Acer*. It is therefore not a part of the original specimens from Salem, N. C., upon which his description was based, and in reality is not *Sphaeria gyrosa*, but a species of *Nectria*, which Schweinitz incorrectly identified as *S. gyrosa*. Portions of this same specimen are found in Berkeley's herbarium at Kew and in the Curtis herbarium at Harvard. They are clearly the *Nectria* referred to above from Torrey. In this connection, it may be noted that E. Hitchcock in 1829 (42, p. 63) reports *Sphaeria gyrosa* Schw. from Amherst, Mass., and states in the preface to his list that Dr. Torrey assisted in the determination of the cryptogams.



"CANKERS" CAUSED BY *ENDOTHIA PARASITICA* ON *CASTANEA DENTATA*. $\times \frac{1}{2}$.



1



2



*Sphaeria
gyrosa* Schw.

HERB. MUS. PARIS.

*Melogramma
gyrosum*

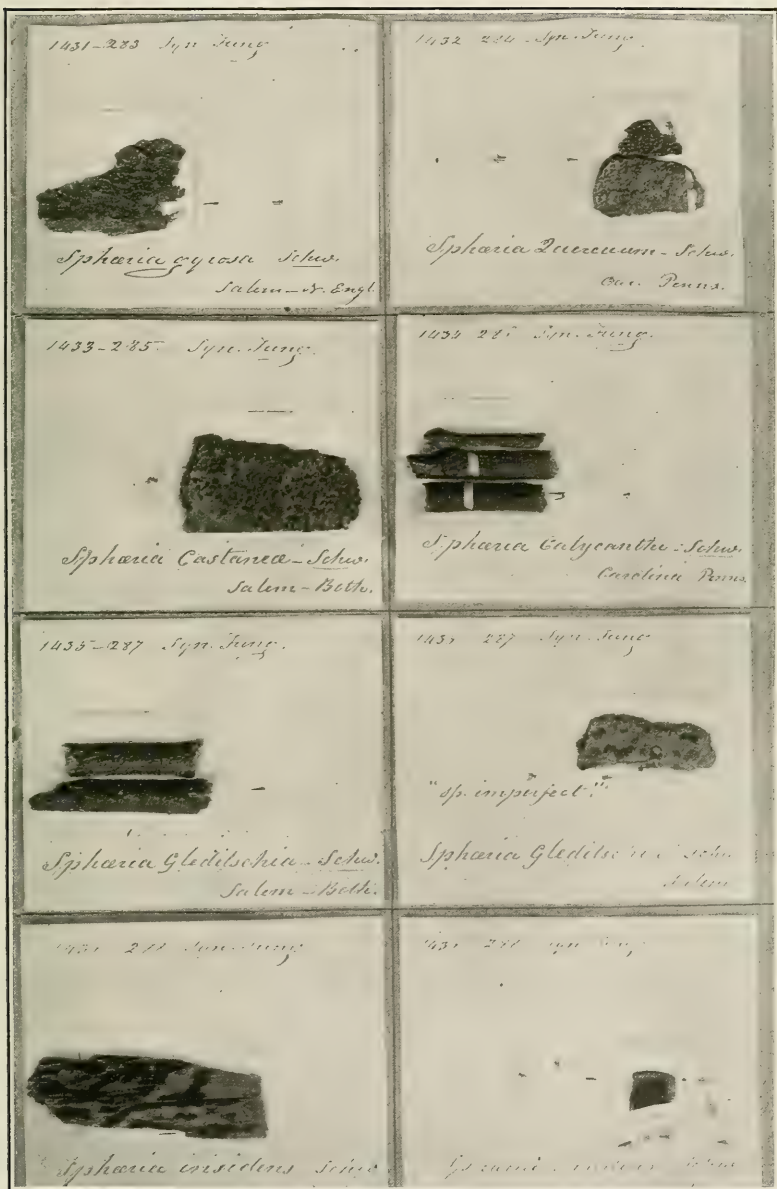
*Carthagenia
(Ex. herb. Ad. Brongniart. Anno 1843).*

*Dr. Schweinitz
Ad.*

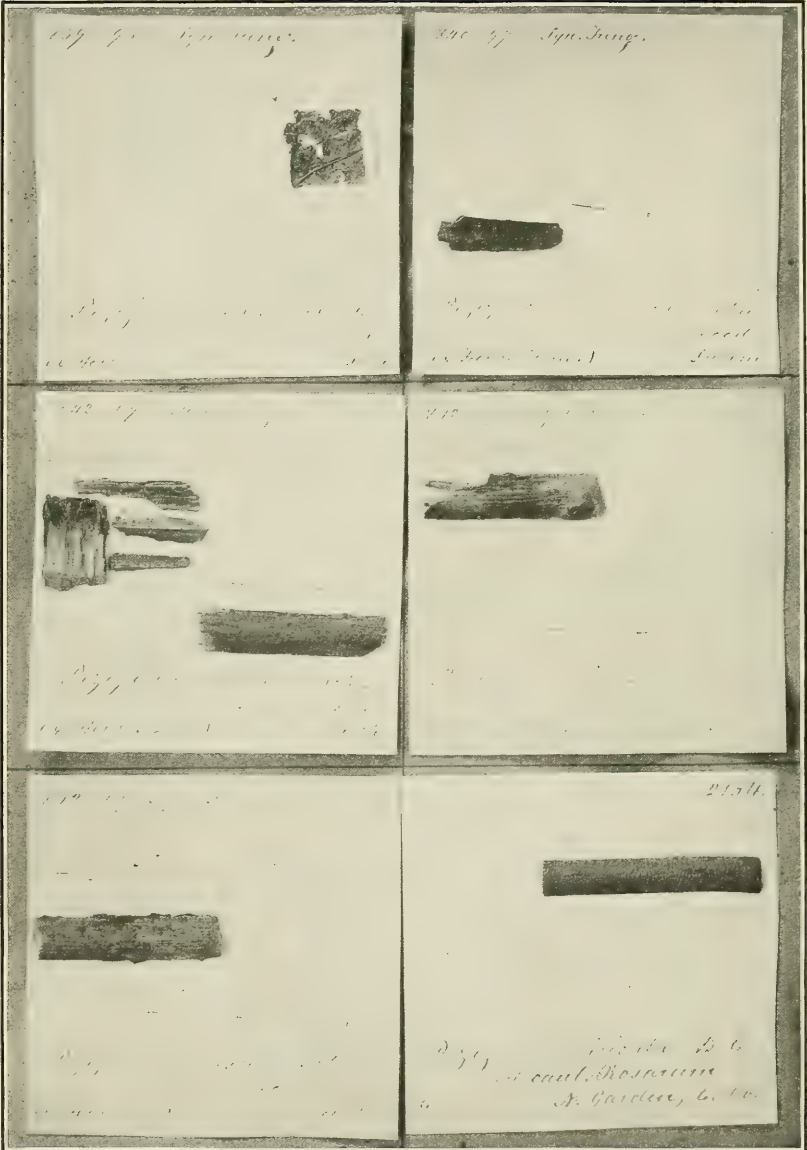
(Ex. herb. Ad. Brongniart. Anno 1843).

FIG. 1.—PERITHECIA AND PYCNIDIAL STROMATA OF ENDOTHIA PARASITICA WITH CANKERS ON CASTANEA DENTATA. FIG. 2.—COTYPE OF SPHAERIA GYROSA SCHW. ON FAGUS.

Specimen now in the Paris Museum sent to Brongniart by Schweinitz, showing Tulasne's label "*Melogramma gyrosum*" and Schweinitz's autograph label.



A SHEET FROM THE MOUNTED PORTION OF SCHWEINITZ'S HERBARIUM AT THE PHILADELPHIA ACADEMY OF SCIENCES, SHOWING SPECIMENS AS PREPARED AND LABELED BY MICHENER.



A SHEET FROM MICHENER'S HERBARIUM, SHOWING A PART OF SCHWEINITZ'S TYPE OF PEZIZA CINNABARINA (UPPER RIGHT HAND CORNER); ALSO SHOWING CLEARLY THAT THE MOUNTING AND LABELING OF THIS AND SCHWEINITZ'S COLLECTION WERE DONE BY THE SAME PERSON.

This seems to explain the origin of the specimen which Schweinitz received from Dr. Torrey. The writers have searched in vain for *Endothia gyrosa* in Amherst and vicinity and they know of no collections of the fungus from Massachusetts. No specimens upon which Hitchcock's list was based have been located.

Since it can be clearly shown that little or none of the original type collection of this species is in the Philadelphia Academy collection it must be looked for elsewhere. It is found by reference to Schweinitz's correspondence and manuscripts, which have been carefully examined by the writers through the courtesy of the Philadelphia Academy and the descendants of Schweinitz, and also by studies in foreign herbaria that he divided his specimens with many of his European and American correspondents. As he does not appear to have kept any duplicates separate from his regular collection it seems probable that the specimens he distributed were taken from the original packets. Thus in some cases, apparently all of a type specimen was removed from the original packet. In fact, in one instance (73, p. 5) he states that he sent his only specimen of a species of *Hypoxylon* to Dr. Schwaegrichen, of Leipzig.

It seems rather certain from statements made by Schwaegrichen in his introduction to Schweinitz's paper on the fungi of North Carolina (72) that specimens of a large number, if not all, of the species represented in that work were sent to him. The types or parts of the types should therefore be found in Schwaegrichen's herbarium. In spite of all their efforts, however, through correspondence and personal search in Europe, the writers have been unable to locate Schwaegrichen's collection of fungi. They found, however, in the herbarium of the University of Leipzig a small bit of a specimen labeled "*Sphaeria gyrosa* Schwein. Juglans Fagus Carolina D. Schwaegrich. dd 5-21 K. Z." This specimen is evidently a part of the original collection of Schweinitz which was sent to Schwaegrichen and given by him to Dr. Kunze. The host is apparently neither Juglans nor Fagus, but seems to be Quercus. It may be noted in this connection that in spite of diligent search by the writers and various other collectors no specimen of *Endothia* has yet been found on Juglans in this country. Neither have the writers been able to find any specimen in the various herbaria examined. They have concluded, as a result of their studies, that the mention of Juglans by Schweinitz was an error in the identification of the host, which it is believed was really Quercus, the host upon which *E. gyrosa* is most frequently found in the South, and especially in the vicinity of Salem. According to the American Code,¹ however, the specimen which should be taken as the type in this case is the one on

¹ American Code of Botanical Nomenclature. Canon 14, b. Bulletin, Torrey Botanical Club, vol. 34, p. 172. 1907.

Fagus, as this is the first-mentioned host in the original description. No specimen of this species on *Fagus* from Schweinitz was found in Kunze's collection. However, authentic specimens from Schweinitz on *Fagus* have been found in Fries's herbarium at Upsala, in Hooker's herbarium at Kew, and in Brongniart's herbarium in the Paris Museum. The last, which is the largest and best specimen, is shown in Plate II, figure 2. Microscopic studies of the specimens at Paris and Kew show only pycnidia with pycnospores. The writers were unable to examine microscopically the specimen in Fries's herbarium, but it agreed in all macroscopic respects and also, so far as could be determined with a hand lens, with the Paris and Kew specimens. These specimens agree with all the material collected on *Fagus* from various localities in the South. Studies of numerous collections of *E. gyrosa* have shown that the pycnidial form can be distinguished with certainty from any of the other species of *Endothia* at present known. The connection between this pycnidial form and the perithecial form as described has been demonstrated by pure cultures from ascospores and also by the association of typical pycnidia and pycnospores with perithecia and ascospores in the same stroma. There appears to be no reasonable doubt, therefore, that the specimens collected by Schweinitz on *Fagus* were the pycnidial form of *Endothia gyrosa*, and the specimen in the Paris Museum which was sent by Schweinitz to Brongniart about 1825 may properly be considered a cotype of Schweinitz's species. The specimen from Schweinitz in Kunze's herbarium at Leipzig also proves on microscopic examination to be the pycnidial form of the same fungus. It is probable from the evidence at hand that Schweinitz did not collect any specimen showing ascospores of this fungus. However, the specimen in Kunze's herbarium shows some perithecia evidently immature and without spores. A part of the specimen from Schweinitz in Fries's herbarium shows stromata on a piece of bark, evidently not *Fagus*, but probably *Quercus*. This also appears to be pycnidia only.

The specimen referred to by Clinton (18), which was found in the original packet of Schweinitz at Philadelphia with *Sphaeria enteromela*, is also undoubtedly the pycnidial form of *E. gyrosa*, which closely resembles some early stages in the development of species of *Hypoxylon*, especially *H. enteromela*. These species may be easily confused with each other, and this would seem to be a probable explanation of the accidental presence of this specimen in this packet. Another point of interest in this connection is the fact that in spite of diligent search on the part of the writers and many other collectors and an examination of numerous specimens of *Endothia* on *Fagus* in all stages of development and from different localities only *Endothia gyrosa* has been found on this host. Of

course, it can not be positively stated that *E. fluens* does not occur on *Fagus* in this country, but if it does it must be rare. In this connection, it is also perhaps worthy of note that, notwithstanding the mention of *Fagus* as a host in Europe, the writers have never seen any European specimens of *Endothia* on this host. The specimens so named by Roumeguere and distributed as No. 989 Fun. Gal. on beech are, according to several specimens examined, evidently a young condition of some *Hypoxylon*, probably *H. coccineum*, which in this state bears a superficial resemblance in form and color to the stromata of *Endothia*, but can be easily distinguished by the dark-brown or blackish color of the interior of the stroma. The identity of Schweinitz's *Sphaeria gyrosa* with the long ascospore form of *Endothia* shown on Plate VII is based on careful microscopic study of the stromata and measurement of the pycnospores from four specimens of the original collections of Schweinitz in North Carolina, three on *Fagus* and one labeled *Juglans*. The three on *Fagus* show the typical pycnidial stromata and pycnospores of the species, either of which is sufficient for positive identification when thoroughly known. The specimen referred to by Schweinitz as on *Juglans* also shows typical pycnospores of *E. gyrosa*. The evidence, as stated above, leaves no reasonable doubt as to the identity of the fungus which Schweinitz described as *Sphaeria gyrosa*.

According to a specimen which is probably a portion of Schweinitz's type found in Michener's herbarium, *Peziza cinnabarina* Schw. is the pycnidial form of *E. gyrosa* (Schw.) (See Pl. IV.) It is the form with small pycnidia on bare wood of *Liquidambar*. This was first reported by Schweinitz as "*Peziza flammea* A. and S." and later changed as above. Later Saccardo (69, vol. 8, p. 399), thinking that this was a Discomycete, transferred it to the genus *Lachnella*.

The other American species of *Endothia* which was described by Schweinitz as *Sphaeria radicalis* and first published by Fries in 1828 (31, p. 73) has also until recently been more or less misunderstood. The only specimens of this species found at present in Schweinitz's mounted collection at the Philadelphia Academy of Science is a small piece of bark of an oak root bearing a few pycnidial stromata. No host was given in Fries, but Schweinitz in 1832 (74 p. 197) gives *Fagus* as the host. That this was an error and that the host was really *Quercus* and not *Fagus* is clearly indicated by all of Schweinitz's specimens examined, not only those in the Philadelphia Academy but those found in several herbaria in Europe and one in Curtis's herbarium at Harvard, and also in Schweinitz's autograph label on the original packet in his herbarium. A photograph of this packet is shown in Plate VI.

The description of this species was first published by Fries in 1828 (31, p. 73). Schweinitz's specimen at the Philadelphia Academy

shows only pycnidia. (See Pl. V, fig. 2.) His description, however, as well as his unpublished illustrations preserved in the library of the Academy, show clearly that perithecia were present in the material from which the description was made. This is also conclusively shown by authentic specimens from Schweinitz in at least two European collections, those of Fries at Upsala and Hooker at Kew. A microscopic examination of these specimens shows good perithecia and mature ascospores having the characters and measurements given elsewhere in this paper for *Endothia fluens* (Sow.). (See Pl. XVII, fig. 9.) As there is no indication in Schweinitz's writings or in his manuscript notes and records that he made more than one collection of this species, there is no reason to doubt that the material at Upsala and Kew is a part of that upon which he based his description of *Sphaeria radicalis* Schw. The true type specimen of the species is that in Fries's herbarium upon which he based his description, which was added to the diagnosis sent by Schweinitz.

One year after the description of this species from America it was reported from Italy by Rudolph, in 1829 (66, p. 393), and in 1830 Fries (32, p. 541) himself reports the fungus from France. This species had, however, been collected and described before in its pycnidial condition in 1814 by Sowerby (79, pl. 438) under the name of *Sphaeria fluens*. This was reported in 1836 by Berkeley (8, p. 254) as *Sphaeria gyrosa* Schw. A microscopic study of the original material of this species, which was collected by Charles Lyell on chestnut in the New Forest in southern England and is now preserved in the Kew Herbarium, leaves no doubt that it is the pycnidial form of *Endothia radicalis* (Schw.). Plate XVII, figure 3, shows pycnosporos from Sowerby's specimen at Kew. This specimen agrees with Sowerby's illustration and is apparently the one from which this figure was made. The pycnospore masses are somewhat larger than usual; otherwise it is typical of *E. radicalis* Schw.

At first it did not seem possible to distinguish the species of *Endothia* in their pycnidial condition, but thorough microscopic studies of large quantities of material in the field and laboratory in both America and Europe have shown that the two sections of the genus and some of the species can usually be separated with certainty in this stage of their development, as indicated by the tables of measurements and in the photographs of pycnosporos, and especially by the stromata of the different species.

The first description of the ascospores of *E. radicalis* was given in 1858 by Currey (21, p. 272), who examined the specimens from Schweinitz in Hooker's herbarium at Kew. Currey figured what he believed to be four ascospores. Two are apparently typical *E.*

fluens; the other two are more than 1-septate and belong to some other organism. Cesati and De Notaris, in 1863 (11), first definitely referred *Sphaeria radicalis* Schw. to *Endothia*. Up to this time *Sphaeria gyrosa* and *Sphaeria radicalis* were generally regarded by mycologists as separate species and were placed by Schweinitz and Fries in different groups of the genus *Sphaeria*, though they both mention a similarity in external appearances.

In 1863 the Tulasnes, in their epoch-making work on the fungi (83, pp. 87-89), made a careful microscopic study of the specimens from Schweinitz preserved in the Paris Museum and also specimens received from De Notaris, Berkeley, and other collectors. At that time no ascospores of *Sphaeria gyrosa* had apparently been described by mycologists. The material of *S. gyrosa* from Schweinitz which the Tulasnes found in the Paris Museum included the specimen on *Fagus* which had been sent by Schweinitz to Brongniart. There seems to be no evidence that the Tulasnes examined other specimens from Schweinitz or that they examined any specimens showing ascospores of the true *Sphaeria gyrosa*. This is indicated by their description and measurements of the ascospores. From their studies of Schweinitz's specimens and from other Carolina specimens sent them by Berkeley they concluded that *Sphaeria gyrosa* and *Sphaeria radicalis* are the same species and called it *Melogramma gyrosum*.

Fries (33, pp. 385-386) had earlier (1849) reported *Sphaeria gyrosa* as occurring in southern Europe. This report was apparently based upon specimens of pycnidial stromata of *E. fluens*, somewhat larger and more irregular in shape than usual, collected in western France by Guepin and Levieux and already referred to.

The statement of the Tulasnes (83, pp. 84-89) in regard to the identity of these species was accepted by practically all mycologists down to 1912, when the discussion in regard to the origin and relationships of *Endothia parasitica* commenced. Ellis and Everhart in 1892 (26, p. 552) apparently figured the true *E. gyrosa* Schw. but cited exsiccati of both *E. gyrosa* and *E. fluens* and gave the ascospore characters and measurements of *E. fluens*, apparently copied from Winter (85, p. 803), as the spores figured do not agree with the description.

THE SPECIES OF ENDOTHIA.

ENDOTHIA Fries, 1849, Sum. Veg. Scand., p. 385.¹

SYNONYMS:

Endothiella Sacc., 1906, in Ann. Mycol., v. 4, no. 3, p. 273. Type species, *E. gyrosa* Sacc., 1 c.

Calopactis H. and P. Syd., 1912, in Ann. Mycol., v. 10, no. 1, p. 82. Type species, *C. singularis*, 1 c.

¹ All references to literature in synonymy are given in full in "Literature cited," p. 77.

Stromata subcorticular in origin, variable in size and shape, pustular to subspherical, subcoriaceous to friable, sometimes confluent, surface light auburn¹ or chestnut to mahogany red, capucine yellow or cadmium orange to scarlet within; pycnidial and perithecial stromata the same or similar; pycnidia few to numerous, consisting of simple cavities or complex and irregular chambers; pycnospores minute, simple, bacilliform to oblong, yellowish to reddish in mass; perithecia deeply immersed, in one or more irregular layers, usually black when mature, with long necks, black within, colored like the stroma without; asci clavate to oblong fusoid, 8-spored, usually without paraphyses; ascospores oblong fusoid or subellipsoid to cylindric or allantoid cylindric, uniseptate or non-septate, hyaline to pale yellowish.

Section 1.—Ascospores short cylindric to allantoid, continuous or pseudoseptate.

ENDOTHIA GYROSA (Schw.) Fries, 1849, *Sum. Veg. Scand.*, p. 385. p. p.

SYNONYMS:

- Pycnidia: *Sphaeria gyrosa* Schw., 1822, *Syn. Fung. Car. Sup.*, p. 29, no. 24.
Peziza flammea Schw. (not. Alb. and Schw.), 1822, *Syn. Fung. Car. Sup.*, p. 93, no. 41, p. p. ad Liquidambar.
Sphaeria gyrosa Fries, 1822, *Syst. Mycol.*, v. 2, p. 419.
Peziza gyrosa Spreng., 1827, *Syst. Veg.*, v. 4, pars. 1, p. 515.
Peziza cinnabarina Schw., 1832, *Syn. Fung. Am. Bor.*, p. 173.
Melogramma gyrosum, L. R. and C. Tul., 1863, *Selecta Fung. Carpol.*, t. 2, p. 87. p. p. min.
Melogramma gyrosum M. A. Curtis, 1867, *Cat. Indig. Nat. Plants*, p. 143.
Endothia gyrosum (Tul.) Fekl., 1869, *Symb. Mycol.*, p. 226.
Melogramma gyrosum Tul., Rav., 1879, *Fung. Amer. Exs.*, no. 352.
Lachnella cinnabarina Sacc., 1889, *Syll. Fung.*, v. 8, p. 399.
Perithecia: *Sphaeria gyrosa* Schw., Rav., 1852, *Fung. Car. Exs.*, no. 49.
Melogramma gyrosum Tul., Cooke, 1878, *in Ann. N. Y. Acad. Sci.*, v. 1, no. 5/6, p. 185.
Endothia gyrosa Fekl., Sacc., 1882, *Syll. Fung.*, v. 1, p. 601. p. p. min.
Endothia gyrosa Schw., Ell. and Ev., 1887, *No. Amer. Fung. Exs.*, no. 1956.
Endothia gyrosa (Schw.) Ell. and Ev., 1892, *No. Amer. Pyren.*, p. 552, p. p.
Endothia radicalis (Schw.) Farl., Clint., 1912, *in Science*, n. s., v. 36, no. 939, p. 908.
Endothia radicalis (Schw.) Shear, 1912, *in Phytopathology*, v. 2, no. 5, p. 211.
Endothia radicalis (Schw.) Fries, P. J. and H. W. And., 1912, *in Phytopathology*, v. 2, no. 5, p. 210.

TYPE SPECIMEN.—The type in Herb. Schw. is wanting. A cotype is in Herb. Museum of Paris.

PYCNIDIA.—Stromata corticular or subcorticular, pulvinate to tubercular, rugulose, scattered or gregarious, occasionally confluent, 1.5 to 3 mm. in diameter by 1.5 to 2 mm. high, orange chrome when young to chestnut when mature,

¹ In the following descriptions of cultures and elsewhere throughout this paper, the names of colors are taken from Ridgway's recent work on color nomenclature (64).

becoming almost black when old and weathered, cadmium orange within; pycnidia consisting of numerous irregular labyrinthiform chambers in the stroma, separated by walls of varying thickness and opening by irregular pores in the surface of the stroma; sporophores cylindric or slightly tapering toward the apex, 6 to 9 μ long; pycnosporos oblong, straight or sometimes slightly curved, appearing hyaline when separate, warm buff to ochraceous buff or darker, according to mass and moisture content, 3 to 4 by 1.5 to 2 μ .

PERITHECIA.—Stromata the same or similar to those producing pycnidia; perithecia dark, membranous, few to many, mostly 25 to 50, usually arising in the lower portion of the stroma, 150 to 300 μ in diameter, very irregularly arranged in one to several layers, prolonged into slender necks which penetrate the stroma above and sometimes protrude somewhat, terminating in a short conical ostiole; asci oblong fusoid or subclavate, very short stipitate, 25 to 30 by 6 to 7 μ ; ascospores irregularly biseriolate, cylindric to allantoid, 7 to 11 by 2 to 3 μ , mostly 7.5 to 10 by 2 to 2.5 μ , hyaline when separate, slightly yellowish in mass, with a very thin gelatinous envelope when mature.

CULTURAL CHARACTERS.—Cultures one month old on white corn meal show an abundant thick growth of mycelium producing irregular tubercular masses resembling pycnidial stromata, but without spores. The surface color is capucine buff. The medium usually changes to perilla purple. It is distinguished from *E. singularis*, its nearest relative, by its more rapid growth and the formation of the large tubercular masses.

HOSTS.—Exposed roots and branches: *Quercus alba*, *Q. coccinea*, *Q. falcata*, *Q. georgiana*, *Q. ilicifolia*, *Q. imbricaria*, *Q. marylandica*, *Q. nigra*, *Q. phellos*, *Q. prinus*, *Q. rubra*, *Q. velutina*, *Q. virginiana*, *Liquidambar styraciflua*, *Fagus americana* and *F. sylvatica* cult. vars., *Castanea dentata* and cult. vars., and *Vitis* sp. (25).

A specimen of this species collected by Ravenel has the host given as maple (*Acer*), but microscopic examination shows it to be *Liquidambar*.

TYPE LOCALITY.—Salem, N. C.

GEOGRAPHICAL DISTRIBUTION.—Southwestern Connecticut to central Michigan, southward to Florida and Texas; also Kansas and California.

ILLUSTRATIONS.—Ell. and Ev., 1892, No. Amer. Pyren., pl. 36, fig. 68; Clint. 1913, in Conn. Agr. Exp. Sta. Rpt., 1911, 1912, pl. 28, fig. a, d, and g.

EXSICCATI.—Pycnidia: Baker, Pl. Pac. slope, 722, on *Quercus agrifolia*; Rav. Fung. Amer., 352, on *Quercus*. Perithecia: Ell. and Ev. No. Amer. Fung., 1956, on *Quercus*; Rav. Fung. Car., 49, on *Quercus* and *Liquidambar*.

ENDOTHIA SINGULARIS (H. and P. Syd.) S. and S. nov. comb.

SYNONYMS:

Pycnidia: *Calopactis singularis* H. and P. Syd., 1912, in Ann. Mycol., vol. 10, no. 1, p. 82.

Endothia gyrosa Ell. and Ev., in Herb. N. Y. Bot. Gard.

Endothia gyrosa (Schw.) Fckl. Höhnelt, 1913, in Sitzber. K. Akad. Wiss. [Vienna], Math. Naturw. Kl., Abt. 1, Bd. 122, Heft 2, p. 298.

TYPE SPECIMEN.—H. and P. Syd., Fung. Exot., no. 88, on *Q. gambellii*.

PYCNIDIA.—Stromata corticular, erumpent, depressed globose, sometimes irregular, scattered, or gregarious, 3 to 5 mm. wide by 2 to 4 mm. high, outer wall thick, coriaceous, becoming brittle, mahogany red without, scarlet within; pycnidia consisting of innumerable nearly spherical cavities throughout the stroma, 25 to 35 μ in diameter, the walls disintegrating into a powdery mass and the whole set free by the irregular rupture of the stroma wall, usually leaving a cup-like basal portion attached to the bark; sporophores, according to the Sydows,

short, hyaline, subulate, 6 to 8 by $1\ \mu$; pycnospores ovoid oblong, hyaline, the contents of each pycnidial cavity adhering in a globular mass, when set free, 3 to 4 by 1 to $1.5\ \mu$.

PERITHECIA.—Stromata the same or similar to those producing pycnidia; perithecia membranous, few to many, usually 100 or more, 200 to $350\ \mu$ in diameter, irregularly arranged in several series, prolonged into slender necks which sometimes protrude from the stroma; ostioles depressed conical; asci, oblong cylindric or subclavate to fusoid, substipitate, 25 to 35 by 4.5 to $5.5\ \mu$; ascospores irregularly biseriate, cylindric to allantoid, with a thin gelatinous envelope, hyaline when separate, slightly yellowish in mass, 7 to 11 by 1.5 to $3\ \mu$; mostly 7.5 to 10 by 2 to $2.5\ \mu$.

CULTURAL CHARACTERS.—Cultures one month old on white corn meal have a cadmium and orange to capucine buff mycelium. It is distinguished from *E. gyrosa* by its slower growth and brighter color and the want of tubercular, stromalike masses. No spores of this species have been produced in any of the writers' cultures.

HOSTS.—*Quercus gambellii*, *Q. leptophylla*, *Q. nitescens*, *Q. utahensis*. Bethel also reports it on *Q. pungens*.

TYPE LOCALITY.—Palmer Lake, Colo.

GEOGRAPHICAL DISTRIBUTION.—Colorado and New Mexico.

ILLUSTRATIONS.—Pycnidia: H. and P. Syd., 1912, in *Ann. Mycol.*, vol. 10, no. 1, p. 82, figs. 1-5.

EXSICCATI.—Pycnidia and perithecia: H. and P. Syd., *Fung. Exot.*, 88, on *Quercus*. Pycnidia: Bart. *Fung. Col.*, 4002, on *Quercus utahensis*.

In shape and size of pycnospores and ascospores this species closely resembles *E. gyrosa*, but is easily separated by the much greater size of its stromata, its brighter color and very numerous, small, regular pycnidial cavities and more numerous perithecia, as well as its geographical distribution.

The specimens of the Sydow exsiccati, No. 88, in the Pathological and Mycological Collections of the Bureau of Plant Industry show both pycnidia and perithecia.

Section 2.—Ascospores oblong fusiform to oblong ellipsoid, uni-septate when mature.

ENDOTHIA FLUENS (Sow.) S. and S. nov. comb.

SYNONYMS:

Pycnidia: *Sphaeria fluens* Sow., 1814, *Col. Fig. Engl. Fungi*, Sup. pl. 438, figs. 1, 2.

Sphaeria gyrosa Berk., 1836, *Brit. Fungi*, p. 254. Not Schw.

Endothia gyrosa Fries, 1849, *Sum. Veg. Scand.*, p. 385. p. p. Europ.

Sphaeria radicalis Fckl., 1861, *Enum. Fung. Nass.*, p. 76, no. 640.

Endothia gyrosum Fckl., 1869, *Symb. Mycol.*, p. 226. p. p. spec. cit.

Endothia gyrosa (Schw.) Fckl., forma *castaneae vescae* Sacc., 1876, *Mycol. Ven. Exs.*, no. 929.

Endothiella gyrosa Sacc., 1906, in *Ann. Mycol.*, v. 4, no. 3, p. 273.

Perithecia: *Sphaeria radicalis* Schw., Fries, 1828, *Elenchus Fung.*, v. 2, p. 73.

Sphaeria radicalis Schw., Rudolphi, 1829, in *Linnaea*, Bd. 4, Heft 3, p. 393.

Sphaeria radicalis Schw., Fries, 1830, in *Linnaea*, Bd. 5, Heft 4, p. 541.

7. Trail *Verfuliles*10. *S. radicalis* Lot

Rather rare, & not without affinity to *S. gregaria*, occurs on the roots of dead oaks, where they appear above ground, budding from the bark. Salem & Betel.

S. gregaria circumspans ex epidermide radicali fibr. secunda regosa, aurantio-miniatu, subsantia fibrilis (crassiuscula), intus pallide aurantiacea; peritheciis minutis subconfluentibus. Perithecia in implexu atrox, in collum longiusculum protractis, saepe in pueris sic alveatum, apertis, intus nigris cylindricis aut irregularibus, ^{periclytis} minutis, fibrillis circumdatis, nigro periclytis. Vix lineam lat et longa.

1

1269 - 124 - Syn. Jung.

Sphaeria radicalis
Lot
Salem.

Sphaeria radicalis
Salem
in herb. Schweinitz

2

Sphaeria radicalis - Schreb.

Salem.

FIG. 1.—PHOTOGRAPH OF SCHWEINITZ'S MANUSCRIPT NOTES, WITH HIS DESCRIPTION OF *SPHAERIA RADICALIS*. FIG. 2.—SPECIMEN OF *S. RADICALIS* IN THE MOUNTED COLLECTION OF SCHWEINITZ, AS PREPARED BY MICHENER; ALSO ORIGINAL PACKET WITH SCHWEINITZ'S AUTOGRAPH LABEL.

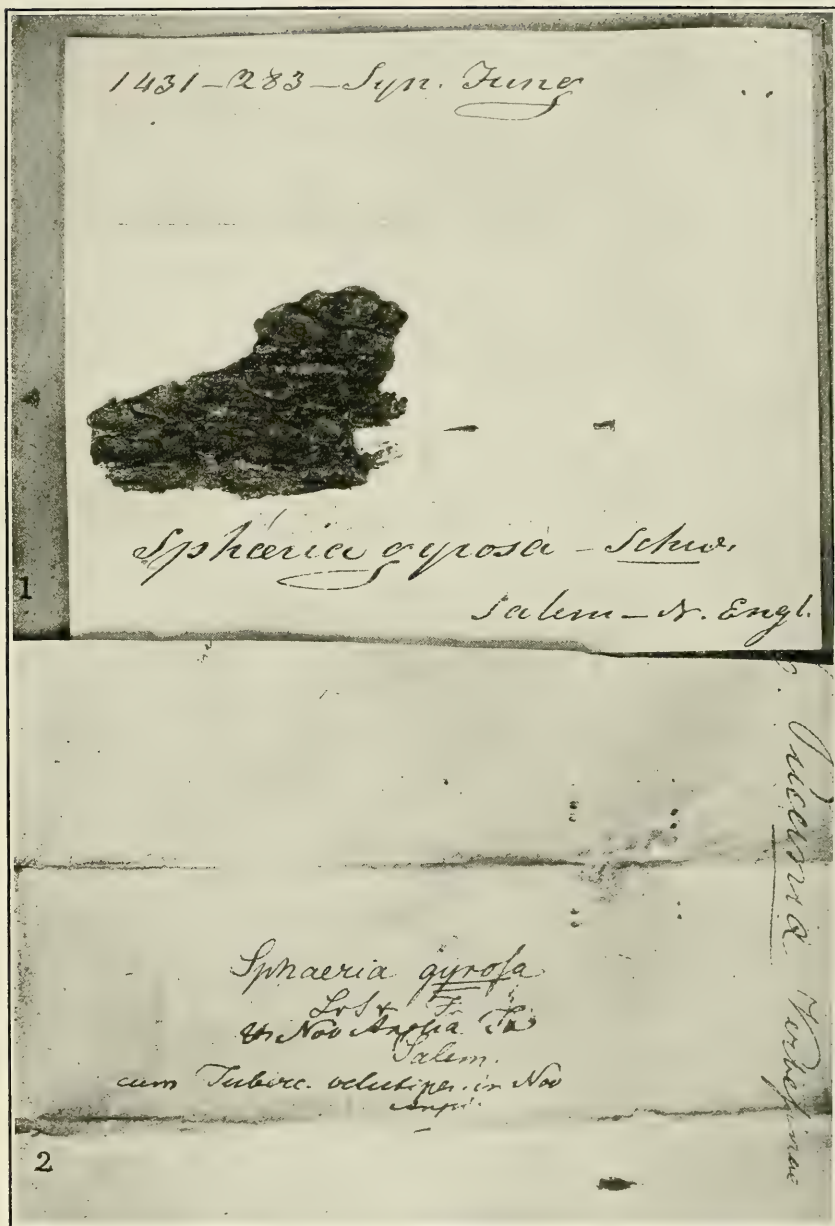


FIG. 1.—PHOTOGRAPH OF THE SPECIMEN IN SCHWEINITZ'S HERBARIUM MOUNTED BY MICHENER. NOT TRUE ENDOTHIA GYROSA BUT A NECTRIA. FIG. 2.—ORIGINAL PAPER PACKET IN WHICH SCHWEINITZ'S TYPE MATERIAL OF *E. GYROSA* WAS PRESERVED, WITH HIS AUTOGRAPH LABEL.



ENDOTHIA GYROSA GROWING ON THE RECENTLY CUT END OF A LIVING BRANCH OF FAGUS SP. NATURAL SIZE.



MYCELIAL FANS OF *ENDOTHIA PARASITICA* UNDER THE BARK OF *CASTANEA DENTATA*.

Illustration from Heald (39), by courtesy of I. C. Williams, Pennsylvania State Forestry Department.

SYNONYMS—Continued.

Perithecia—Continued.

Sphaeria radicalis Schw., 1832, Fun. Am. Bor., p. 197.

Sphaeria radicalis Schw., Mont., 1834, in Ann. Sci. Nat. Bot., s. 2, t. 1, p. 295.

Sphaeria (Diatrype) *radicalis* Fries, Currey, 1858, in Trans. Linn. Soc. London, v. 22, pt. 3, p. 272, pl. 47, fig. 89. p. p.

Valsa radicalis Ces. and De Not., 1863, in Comm. Soc. Crittog. Ital., v. 1, p. 207.

Endothia radicalis (Schw.) Ces. and De Not., 1863, in Comm. Soc. Crittog. Ital., v. 1, opp. p. 240.

Melogramma gyrosum L. R. and C. Tul., 1863, Selecta Fung. Carpol., t. 2, p. 87. p. p. max.

Sphaeria (Diatrype) *radicalis* Schw., Currey, 1865, in Trans. Linn. Soc. London, v. 25, pt. 2, p. 244.

Endothia gyrosa (Schw.) Fckl., Sacc., 1882, Syll. Fung., v. 1, p. 601. p. p.

Endothia gyrosa var. *rostellata* Sacc., 1882, Syll. Fung., v. 1, p. 602.

Endothia radicalis (Schw.) Wint., 1887, Pilze, p. 803.

Endothia gyrosa Schw., Ell. and Ev., 1892, No. Amer. Pyren., p. 552. p. p.

Endothia virginiana P. J. and H. W. And., 1912, in Phytopathology, v. 2, no. 6, p. 261.

Endothia gyrosa (Schw.) Fries, Clint., 1913, in Conn. Agr. Exp. Sta. Rpt., 1911-12, p. 425.

Endothia pseudoradicalis Petri, 1913, in Atti R. Accad. Lincei Rend. Cl. Sci. Fis., Mat. e Nat., s. 5, v. 22, sem. 1, fasc. 9, p. 654.

Endothia gyrosa (Schw.) Fckl., Höhnelt, 1913, in Sitzber. K. Akad. Wiss. [Vienna], Math. Naturw. Kl., Abt. 1, Bd. 122, Heft 2, p. 298.

TYPE SPECIMEN.—Sowerby in Herb. Kew. on *Castanea sativa*, New Forest, England. Coll. C. Lyell, Apr. 15, 1809.

PYCNIDIA.—Stromata corticular or subcorticular, truncate conical to pulvinate, usually separate and gregarious, but frequently confluent, 0.75 to 3 mm. in diameter by 0.5 to 2.5 mm. high, compact, varying from light auburn to chestnut on the surface and capucine yellow to cadmium orange within; pycnidia consisting of simple or more or less complex and irregular chambers in the stroma, opening by an irregular pore or slit at the apex of the stroma; sporophores usually simple, sometimes branched near the base, cylindric to subclavate, 10 to 13 μ long, sometimes 24 to 30; pycnosporos oblong to rod-like, pale yellowish in mass, 3 to 5 by 1.5 to 2 μ , mostly 3.5 to 4 by 2 μ .

PERITHECIA.—Stromata the same or similar to those producing pycnidia; perithecia membranous, few to many, mostly 15 to 25. 300 to 400 μ in diameter, usually arising in the lower portion of the stroma, irregularly arranged in one to three layers, prolonged into slender necks which penetrate the stroma above and protrude usually from 300 to 600 μ , terminating in conical ostioles; asci oblong fusoid or subclavate, very short stipitate, 30 to 40 by 6 to 8 μ , mostly 30 to 35 by 7 μ , ascospores irregularly biseriata, oblong fusoid or subellipsoid, not constricted at the septum, hyaline with a thin gelatinous envelope, 6 to 10 by 3 to 4.5 μ , mostly 6.5 to 9 by 3 to 4 μ .

CULTURAL CHARACTERS.—Cultures one month old on white corn meal show a compact growth with a nearly smooth surface. The color ranges from light cadmium to empire yellow, and the medium becomes perilla purple. Pycnidia and spores usually appear a little later, forming large erumpent stromata which extrude thick masses of pycnosporos. The light mycelium with large

pycnidial stromata and spore masses are distinguishing characters on this medium.

HOSTS.—America: Exposed roots and branches of *Q. alba*, *Q. coccinea*, *Q. marylandica*, *Q. prinus*, *Q. rubra*, *Q. velutina*, and *Castanea dentata*. Europe: Specimens examined, *Quercus pedunculata*, *Castanea sativa*, *Alnus glutinosa*, *Ulmus campestris*, *Carpinus betula*, and *Corylus* sp. Japan: *Castanea* sp. and *Pasania* sp. It is also reported on *Aesculus*, *Fagus*, and *Juglans* by Traverso.

TYPE LOCALITY.—New Forest, England.

GEOGRAPHICAL DISTRIBUTION.—America: Southern Pennsylvania and Ohio to South Carolina and northern Mississippi. Europe: Southern England, France, South Germany, and Switzerland to southern Italy and Transcaucasia. Asia: Japan.

ILLUSTRATIONS.—Sowerby, 1814, Col. Fig. Engl. Fungi, Sup., pl. 438; Currey, 1858, in Trans. Linn. Soc. London, v. 22, pt. 3, pl. 47, fig. 89 (2 upper spores); Ces. and De Not., 1863, in Comm. Soc. Crittog. Ital., pl. 3; Sacc., 1873, in Atti Soc. Veneto-Trentina Sci. Nat. Padova, v. 2, fasc. 1, pl. 14, fig. 63–65; Sacc., 1883, Gen. Pyren., pl. 6, fig. 6; Ruhl., 1900, in Hedwigia, Bd. 39, pl. 2, fig. 10; Trav., 1906, in Soc. Bot. Ital. Fl. Ital. Crypt., pars 1, v. 2, fasc. 1, p. 180, fig. 34; P. J. and H. W. And., 1913, in Penn. Chestnut Tree Blight Com. Bul. 4, p. 22, fig. 2, A and C; Clint., 1913, in Conn. Agr. Exp. Sta. Rpt., 1911–12, pl. 28, fig. b, e, h, and j; Petri, 1913, in Atti R. Accad. Lincei Rend. Cl. Sci. Fis., Mat. e Nat., v. 22, sem. 1, fasc. 9, p. 656, fig. 1–3.

EXSICCATE.—Pycnidia: Thüm. Myc. Univ., 769, on *Castanea*; Sacc. Myc. Ven., 670, on *Carpinus betula*; Sacc. Myc. Ven., 929, on *Castanea*. Perithecia: Fckl. Fun. Nass., 640, on *Ulmus campestris*; Erb. Critt. Ital., 986, on *Castanea*; Rab. Herb. Viv. Myc., 254, on *Castanea*.

Roum. Fun. Sel. Gal., 989, labeled *Endothia gyrosa* Schw. on beech is apparently young *Hypoxyton coccineum*.

The most important synonyms given here have already been discussed. Of the others the writers have examined the types or collections upon which the identifications were based. All the material of *Endothia* in the herbaria of Cesati, De Notaris, Fuckel, and Berkeley, as well as other smaller collections, has been carefully studied. *E. virginiana* And. and And. has been studied in cultures, as well as typical specimens from the authors of the species, and agrees in every particular with *E. fluens*.

Through the kindness of Dr. Petri a part of the type of his *E. pseudoradicalis* has been examined, but unfortunately no cultures could be obtained from the specimen. The writers have been unable to distinguish his specimen from forms of *E. fluens* which appear to show all the intermediate conditions of variation connecting it with typical *E. fluens*. The ascospores of *E. fluens* are more variable in size and shape than those of any other species of *Endothia* studied. After examining many specimens of this species from Europe, it does not seem possible at present to separate any of them. The case of *E. pseudoradicalis* can not perhaps be regarded as closed until more material of it has been collected and compared in culture. In fact, the slide from the type of *Sphaeria radicalis* Schw. shows ascospores of both the narrow and broad form. The photomicro-

graph, Plate XVII, fig. 9, shows an ascospore which agrees with Petri's description and figures.

ENDOTHIA FLUENS MISSISSIPPIENSIS S. and S. nov. comb.

SYNONYM:

Endothia radicalis mississippiensis Shear and Stevens in U. S. Dept. Agr., Bur. Plant Indus. Cir. 131, p. 4. 1913.

TYPE SPECIMEN.—No. 1782, on *Castanea dentata*, Blue Mountain, Miss., N. E. Stevens, Feb. 13, 1913. Deposited in Pathological and Mycological Collections, Bureau of Plant Industry.

CULTURAL CHARACTERS.—Cultures one month old on white corn meal show a compact, rather uniform surface, the color of the mycelium varying from cadmium orange to xanthine orange. This variety is distinguished from the species by the color of its mycelium, by the numerous small pycnidia thickly scattered over the surface of the culture, and by the lack of any purple color in the medium.

HOSTS.—*Castanea dentata*, *Quercus alba*, and *Q. velutina*.

GEOGRAPHICAL DISTRIBUTION.—Northern Mississippi, Kentucky, Tennessee.

COLLECTIONS EXAMINED.—On *Castanea dentata*: No. 1706 A. pycnidia, Corinth, Miss., T. E. Snyder; no. 708, pycnidia, Dumas, Miss., T. E. S.; no. 1782, ascospores, Blue Mountain, Miss., N. E. S.; no. 1806, ascospores, Blue Mountain, Miss., N. E. S. On *Quercus*: No. 1989, pycnidia, Danville, Ky., N. E. S.; no. 1995, pycnidia, Danville, Ky., N. E. S.; no. 2032, pycnidia, Lexington, Tenn., N. E. S.; no. 2255, pycnidia, Sardis, Miss., S. and S.

No morphological characters have yet been found to distinguish this variety. It is therefore separated on its cultural characters, which are marked and constant. The plant was first collected by T. E. Snyder, of the Bureau of Entomology.

ENDOTHIA LONGIROSTRIS Earle, 1900, in Muhlenbergia, v. 1, no. 1, p. 14.

SYNONYM:

Perithecia: *Diatrype radicalis* (Schw.) Fries, Mont., 1855, in Ann. Sci. Nat. Bot. 4, t. 3, p. 123. Not Schw.

TYPE SPECIMEN.—No. 4340. A. A. Heller, Plants of Porto Rico. In Herb. N. Y. Bot. Garden.

PYCNIDIA.—Stromata corticular, erumpent, gregarious, sometimes confluent, 1 to 3 mm. in diameter, subcoriaceous, surface orange rufous to chestnut, interior zinc orange; pycnidia consisting of irregular labyrinthiform cavities opening by a single large pore or irregular rupture at the apex of the stroma; sporophores slender, somewhat tapering upward, mostly 8 to 10 μ long; pycnospores oblong elliptic, hyaline or yellowish in mass, when expelled forming a stout spore horn or tendril, colored like the stroma on the outside, 2 to 4 by 1 to 1.5 μ .

PERITHECIA.—Stromata the same as those producing pycnidia, but larger and frequently confluent, forming linear series in crevices in the bark; perithecia arising usually at the base of the pycnidial stroma, mostly 3 to 10 in the separate stromata, membranous, 300 to 400 μ in diameter, mostly in a single irregular series, prolonged into long necks, 1.5 to nearly 1 cm. long, sec. Earle, internally black, externally same color and structure as the stroma; ostiole acute; asci oblong cylindric to fusiform, 25 to 35 by 5 to 7 μ , mostly 30 by 6 μ ; ascospores overlapping uniseriate to irregularly biseriate, hyaline, ovoid to ovoid elliptical, 6 to 8.5 by 3 to 4 μ , mostly 7 to 7.5 by 3 to 3.5 μ .

CULTURAL CHARACTERS.—Cultures one month old on white corn meal have a uniform cadmium orange to xanthine orange color. The entire surface is covered with a compact growth, irregularly ridged. Tiny mars orange spore masses are scattered irregularly over the surface. Cultures of this species closely resemble *E. fluens mississippiensis* on this medium, being distinguished by the smaller and much less numerous spore masses. The medium is changed to amber brown just below the mycelium, shading into mars yellow; whereas, in the case of *E. fluens mississippiensis* the color of the medium is very little changed.

TYPE LOCALITY.—"Calcareous hills east of Santurce, Porto Rico, altitude 10 ft."

GEOGRAPHICAL DISTRIBUTION.—Porto Rico and French Guiana.

EXSICCATI.—Pycnidia and perithecia: Heller, Plants of Porto Rico, no. 4340.

This species, which appears to be subtropical or tropical in its range, is known at present from only three collections, the type collection from Porto Rico, a collection by Prof. N. Wille, No. 816, Porto Rico, distributed by the New York Botanical Garden, from which the cultures were obtained; and one made by Leprieur, No. 392, in French Guiana, and determined by Montagne as *Diatrype radicalis* (Schw.). A specimen of this collection apparently labeled by Montagne and preserved in the Delessert Herbarium at Geneva has been examined and found to agree with the type material of *E. longirostris*. It is readily distinguished from *E. tropicalis* by its smaller ascospores and pycnospores, and from *E. fluens* by its narrower and more acute ascospores and the long, slender necks of the perithecia.

ENDOTHIA TROPICALIS Shear and Stevens sp. nov.

SYNONYMS:

Diatrype gyrosa Berk. and Broome, 1875, in Jour. Linn. Soc. [London], v. 14, p. 124.

Nectria gyrosa Berk. and Broome, 1877, in Jour. Linn. Soc. [London], v. 15, p. 86.

Cryphonectria gyrosa (Berk. and Broome) Sacc., in Syll. Fung., v. 17, p. 784. 1905.

Endothia gyrosa (Schw.) Fckl., Hühnel, 1909, in Sitzber. K. Akad. Wiss. [Vienna], Math. Naturw. Kl., Abt. 1, Bd. 118, Heft 9, p. 1480.

TYPE SPECIMEN.—No. 2807 S. and S., on *Elacocarpus glandulifer*, Hakgala, Ceylon, Coll. T. Petch, August, 1913.

PYCNIDIA.—Stromata corticular, pustular to pulvinate, usually gregarious or scattered, rarely confluent, 1 to 5 mm. in diameter, early becoming friable, orange chrome when fresh to sanford brown when old and weathered; pycnidia consisting of numerous irregular cavities in the stroma; sporophores mostly simple, clavate, tapering above, 6 to 10 μ long.; pycnospores continuous, oblong to cylindric, very variable in size and shape, pale yellowish in mass, 3.5 to 7 by 1.5 to 2.5 μ .

PERITHECIA.—Stromata the same or similar to those bearing pycnidia; perithecia black, membranous, collapsing when dry, 5 to 50 or more in a stroma; 250 to 500 μ diameter, irregularly arranged in one to three layers, bearing slender necks which penetrate the stroma and project 0.25 to 1 mm., terminating in acute ostioles; asci oblong or subclavate, nearly sessile, 40 to 50 by 7 μ ; ascospores irregularly biseriate, subelliptical, obtuse, not constricted at

the septum, hyaline with a gelatinous envelope, 7.5 to 10.5 by 3.5 to 5 μ , mostly 8 to 10 by 4 to 4.5 μ .

CULTURAL CHARACTERS.—Cultures one month old on white corn meal show small numerous, thickly scattered pycnidia and spore masses very similar to *E. parasitica*. The mycelium is orange buff to apricot orange. This species differs from *E. parasitica* in culture, chiefly in the brighter color of its mycelium.

HOST.—Rotten logs and stumps of *Elaeocarpus glandulifer*.

TYPE LOCALITY.—Hakgala, Ceylon.

GEOGRAPHICAL DISTRIBUTION.—Only known from Ceylon at present. One other collection of this species, No. 290 G. H. K. T. [Thwaites], N. Eliya, Ceylon, 6,000 feet, has been examined in the Kew Herbarium.

Through the kindness of Mr. T. Petch, of Peredeniya, the writers have received two large collections of this fungus. Some of the material was in a living condition and enabled the writers to obtain pure cultures for comparison with the other species of *Endothia*. This species is closely related to *E. parasitica*, but is readily separated by its larger ascospores and larger and more variable pycnospores and its nonparasitic habit.

ENDOTHIA PARASITICA (Murr.) P. J. and H. W. And., 1912, in *Phytopathology*, v. 2, no. 6, p. 262

SYNONYMS:

Diaporthe parasitica Murrill, 1906, in *Torreyia*, v. 6, no. 9, p. 189.

Valsonectria parasitica Rehm, 1907, *Asc. Exs.*, no. 1710.

Valsonectria parasitica Rehm, 1907, in *Ann. Mycol.*, v. 5, no. 3, p. 210.

Endothia gyrosa var. *parasitica* Clint. 1912, in *Science*, n. s., v. 36, no. 939, p. 913.

Endothia gyrosa (Schw.) Fekl. Höhnelt, 1909, in *Sitzber. K. Akad. Wiss. [Vienna]*, Math. Naturw. Kl., Abt. 1, Bd. 118, Heft 9, p. 1480.

TYPE SPECIMEN.—Herbarium N. Y. Bot. Garden, on *Castanea dentata*, Bronx Park, New York City, Nov. 26, 1905, Coll. W. A. Murrill.

PYCNIDIA.—Stromata corticular, slightly erumpent to truncate conical, usually separate and gregarious, frequently confluent in more or less linear series especially in old rimose bark, 0.75 to 3 mm. in diameter by 0.5 to 2.5 mm. high, varying from capucine yellow when young to auburn when old and weathered; pycnidia consisting of irregular cavities in the stroma, 100 to 300 μ in diameter; sporophores mostly simple, subclavate, acute at the apex, usually 12 to 20 by 1.5 μ , more elongated filaments sometimes reaching 50 μ or more being frequently found among the normal sporophores; pycnospores, oblong to cylindric, rounded at the ends, 3 to 5 by 1.5 to 2, mostly 3.5 to 4.5 by 1.5 to 2 μ , pale yellowish in mass under the microscope; old spore tendrils coral red.

PERITHECIA.—Stromata the same or similar to the pycnidial stromata; perithecia dark, membranous, globose to flask shaped, collapsing when dry, 5 to 50 or sometimes more in a stroma, 300 to 400 μ in diameter, irregularly arranged in one to three layers and bearing slender necks projecting above the stroma, 300 to 600 μ , colored like the stroma on the outside and terminating in acute ostioles; asci oblong elliptical to subclavate, nearly sessile, 30 to 60 by 7 to 9 μ , mostly 40 to 50 by 8 μ ; ascospores irregularly biseriata, ellipsoid, obtuse, sometimes constricted at the septum, hyaline, with a gelatinous envelope, 7 to 11 by 3.5 to 5 μ , mostly 8 to 9 by 4 to 4.5 μ .

CULTURAL CHARACTERS.—Cultures one month old on white corn meal have a white to pale orange yellow surface mycelium and produce numerous minute

pycnidia and pale yellow spore masses. It is distinguished from its nearest relative, *E. tropicalis*, by the lighter color of the mycelium.

HOSTS.—*Castanea dentata*, *C. sativa* and cult. vars., *C. pumila*, *Castanea mollissima* from China and *Castanea japonica* from Japan, *Quercus alba*, *Q. prinus*, *Q. velutina*, *Acer* sp.

It is also reported on *Rhus typhina* and *Carya ovata* by Anderson and Rankin.

TYPE LOCALITY.—Bronx Park, New York City.

GEOGRAPHICAL DISTRIBUTION.—Southern Maine to Ohio and southward to North Carolina; also Missouri, Iowa, Nebraska, British Columbia, China, and Japan.

ILLUSTRATIONS.—Murrill, 1908, in *Torrey*, v. 8, no. 5, p. 111, fig. 2; Petri, 1913, in *Atti R. Accad. Lincei, Rend. Cl. Sci. Fis., Mat. e Nat.*, s. 5, v. 22; sem. 1, fasc. 9, p. 656, fig. 4; Heald, 1913, in *Penn. Chestnut Tree Blight Com. Bul.* 5, pl. 13; Clint. 1913, in *Conn. Agr. Exp. Sta. Rpt.*, 1911/12, pl. 28, fig. c, f, i, and k; P. J. and H. W. And., 1913, in *Penn. Chestnut Tree Blight Com. Bul.* 4, p. 22, fig. 2, B and D; P. J. And. and Rank., 1914, in *N. Y. Cornell Agr. Exp. Sta. Bul.* 347, p. 562, fig. 89.

EXSICCATI.—Pycnidia and perithecia: Rehm, Asc., 1710; Wilson and Seaver, Asc. and Low. Fun., 3; Bart. Fun. Col., 2926; all on *Castanea dentata*.

This species is closely related in its morphological characters to all the species of section 2 of the genus. It is most likely to be confused with *E. fluens*, but shows constant differences, though slight, in size and shape of ascospores. They are predominantly broader and more uniform in shape, as shown by the table of measurements on page 35. In its active parasitic condition on *Castanea* it can always be distinguished by the presence of the mycelial "fans" in the inner bark, as shown in Plate VIII. It has been confused with *E. gyrosa* through an erroneous identification of that species.

MORPHOLOGY AND DEVELOPMENT.

MYCELIUM.

By far the most striking mycelial character is the production by *E. parasitica* of yellow or buff fan-shaped formations of mycelium in the cambium and bark of the host. These "fans" vary from 1 mm. to 1 cm. or more in width, and are composed of radiating hyphæ closely pressed together to form a continuous layer. (Pl. VIII.) So constant are these mycelial fans in their occurrence and so characteristic in their appearance that they furnish the most reliable field character for distinguishing *E. parasitica* from related species and may quite properly be regarded as a specific character when the fungus is growing in living trees.

Anderson and Anderson (2, p. 204) first called attention to the fact that these fan-shaped formations of mycelium are absent from *E. fluens*. Rankin (62, p. 248) states that when the fungus grows saprophytically or while the tree is dormant these fans are not produced. Anderson and Rankin (6, p. 565) report that in inoculations

on *Quercus alba* and *Q. prinus*, *E. parasitica* produced the typical mycelial fans.

Anderson (1, p. 14) considers that the occurrence of these fans is associated with the parasitic habit of the fungus. In his opinion single hyphæ do not possess the power of penetrating the living cells, but the fungus grows on the injured and dead cells about a wound until a quantity of mycelium is accumulated, when it "*en masse* pushes through the living tissues of the bark." This view is also held by Keefer (45, p. 193), who adds that "the action of the advancing mycelial mats seems to be physical rather than chemical, and the cells are mechanically broken to pieces."

Rankin, however, states (62, p. 248) that "The host cells, just in advance of the edges of the fan, are disintegrated and form a distinct gelatinous band, which can be seen with the naked eye." This observation suggests to the writers that some toxic or enzymatic action upon the cells of the host probably occurs before the cells are actually invaded by the fungus hyphæ. Careful investigation of this point should go far toward determining the causes of the parasitism of this fungus. Whatever the cause or function of these fans, they are very characteristic, and the writers have found them invariably in diseased material of *Castanea* in America, as well as in that from China and in two specimens of *E. parasitica* on *Quercus*.

A similar mycelial formation, fanlike in form,¹ is produced by *Armillaria mellea* in the bark of roots attacked by this fungus. Excellent specimens of the *Armillaria* mycelial fans have been presented to the writers by Prof. Wm. T. Horne, of the University of California.

STROMATA.

Under the name *Melogramma gyrosum*, in which they included specimens of both *Endothia gyrosa* and *E. fluens*, the Tulasnes (83, pp. 87-89) described the structure of *Endothia* in some detail. Their description was based chiefly on abundant local material of *E. fluens* collected on *Carpinus betulus* L. during several years, but they also used material sent by Guepin from western France, pycnidial material on chestnut from Italy, American material sent by Schweinitz to Brongniart and preserved in the Paris Museum, and specimens from Carolina sent by Berkeley. According to the Tulasnes (83, p. 87)² the stromata are "developed singly and emerge gradually as so many scattered points with fibers radiating in all directions, soon swell into a yellowish cone, rupture the epidermis above them,

¹ Since this manuscript was completed a very similar mycelial formation has come to the writers' attention. As figured by Nowell (50), pl. 1, *Rosellinia pepo*, when growing under the bark of lime trees, forms mycelial fans resembling those of *Endothia parasitica*.

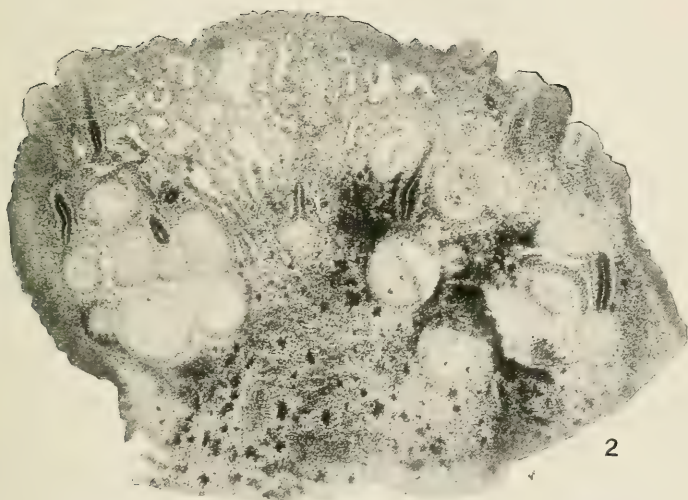
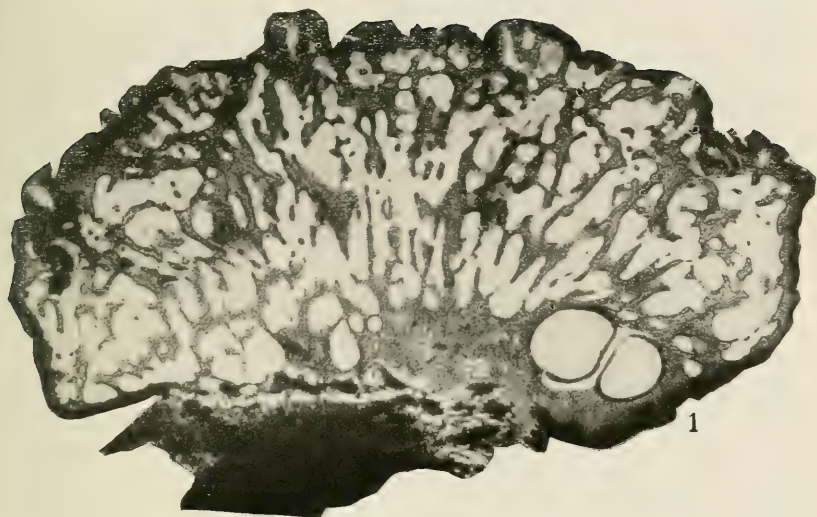
² The portions in quotations are rather free translations of the authors' Latin.

and put forth a very blunt apex. All are composed of a corky, parenchymatous, very dense, soft yellow material. The mature ones attain a diameter of 3 to 4 millimeters and a height of 1 to 2 millimeters, and on the somewhat reddish, and finally rusty red to yellow top, they are marked by black points, the ostioles." The Tulasnes observed that before the stromata reached their full size the pycnidial cavities were formed within them, sometimes "widely open," sometimes "narrow labyrinthine," and that through one or many openings in the top of the pycnidia, the long, twisted, orange tendrils, composed of mucus, and innumerable thin linear spores were expelled. "Perithecia are developed chiefly in stromata destitute of spermogonia, or more often with only a few * * * they arise very abundantly and irregularly, some barely buried in the yellow corklike substance, others lower down and seemingly located in the bark of the host itself."

Although the Tulasnes included all their material under a single species, they noted that the pycnidial stromata of the American specimens (really *Endothia gyrosa*) differed considerably from the European (*E. fluens*). In describing the former, they say (83, p. 88) "The American fungus is said to grow in the bark of *Fagus* and *Juglans* * * * as a whole it abounds with numerous, very small spermatia. Wherefore if it is very thinly sectioned, the pieces, examined with a compound microscope, show cavities just as if you had before your eyes the smallest *Gautieria* or *Balsamia*." The Tulasnes do not try to distinguish definitely between stroma and mycelium, but merely state that the stromata develop within the mycelium.

Ruhland (67), who was the next writer to discuss the morphology of a species of *Endothia*, defines the various portions of the fungus body in detail. According to his definition (p. 16) a "stroma (in distinction from mycelium) is the sum total of that part of the vegetative portion of the fungus body, which, without serving exclusively for absorption, takes part in the formation of the fruit body." He sets aside Fuisting's (36, p. 185) division of the fungus body into an epistroma and a hypostroma, as essentially nothing but the distinction of "conidial layers" and "perithecial stroma."

Ruhland divides the fungus body into an ectostroma and an entostroma. The ectostroma grows "on the upper surface of the parenchyma of the bark, between it and the periderm, and is composed of a generally wide-lumened plectenchyma which does not possess the power of absorption." This portion has the following functions: "The formation of the conidia, the opening and breaking off of the periderm, and the stimulation of the development of the entostroma." The entostroma, on the other hand, according to Ruhland, "lives in the parenchyma of the bark, and while young is in a high degree



ENDOTHIA GYROSA. VERTICAL SECTIONS OF STROMATA ON BEECH. $\times 32$.

FIG. 1.—SHOWING NUMEROUS PYCNIDIAL CAVITIES AND TWO MATURE PERITHECIA.
FIG. 2.—SHOWING MATURE PYCNIDIA AND PERITHECIA SIDE BY SIDE.

Except where otherwise indicated, the photomicrographs of stromata are from unstained sections cut with a freezing microtome.

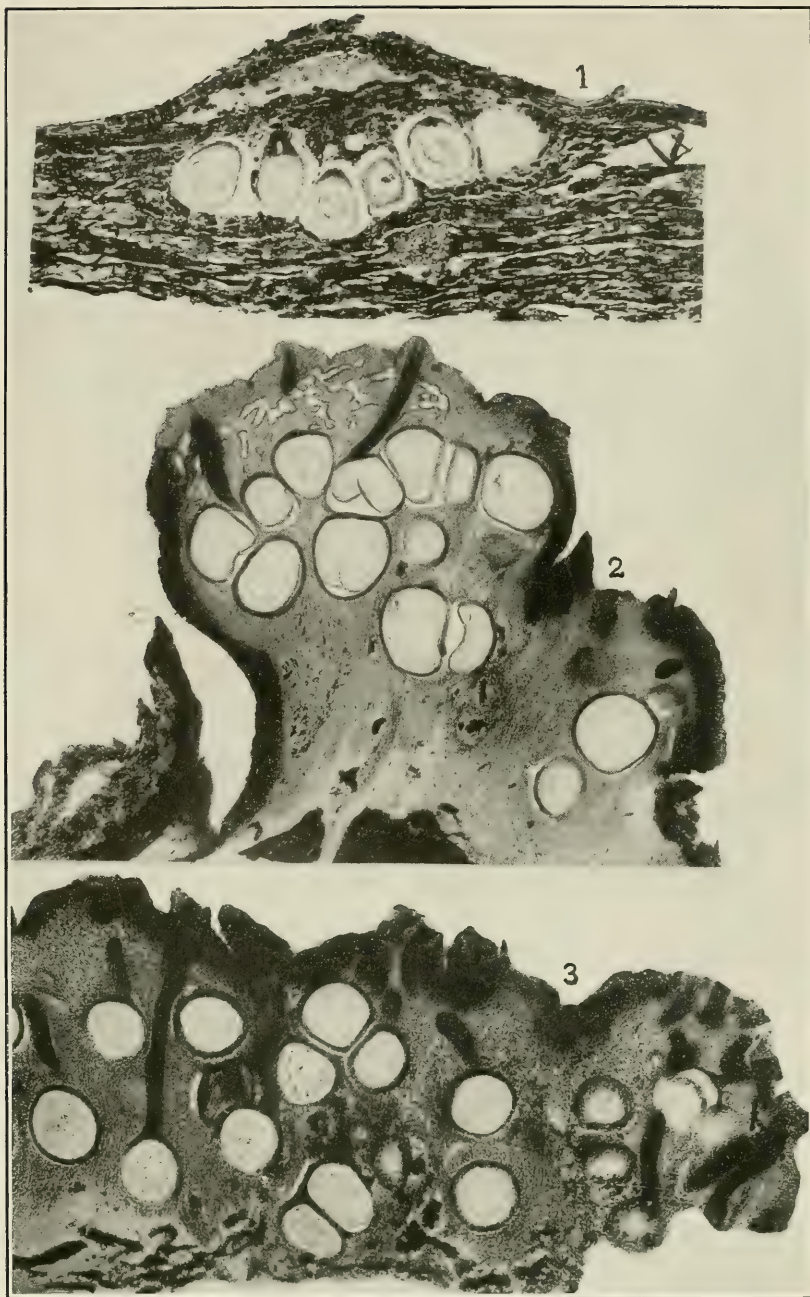
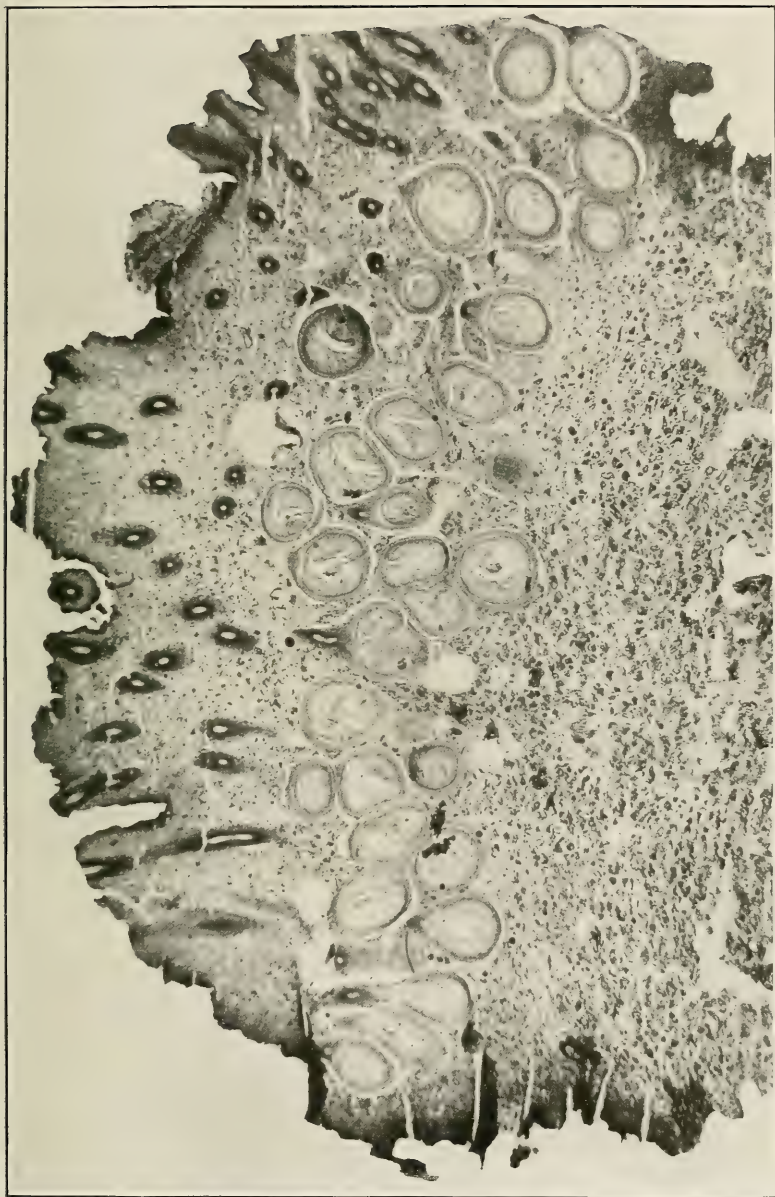
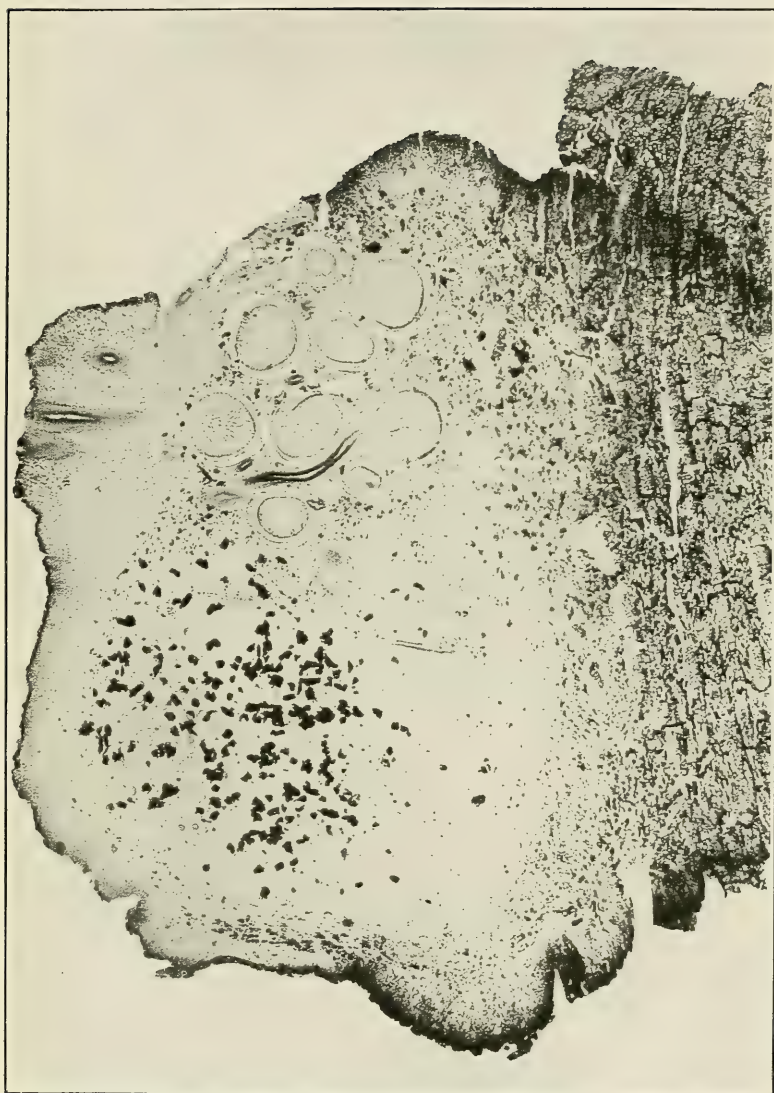


FIG. 1.—*ENDOTHIA FLUENS*. VERTICAL SECTION OF A STROMA FROM ITALY, SHOWING YOUNG PERITHECIA IN A SINGLE LAYER. $\times 49$. FIG. 2.—*ENDOTHIA GYROSA*. VERTICAL SECTION OF A STROMA ON BEECH, SHOWING MATURE PYCNIDIA WITH MATURE PERITHECIA BELOW THEM. $\times 32$. FIG. 3.—*ENDOTHIA GYROSA*. VERTICAL SECTION OF A PORTION OF A LARGE STROMA, SHOWING PERITHECIA IRREGULARLY ARRANGED IN SEVERAL LAYERS.



ENDOTHIA SINGULARIS. VERTICAL SECTION OF A STROMA, SHOWING PERITHECIA ONLY. $\times 32$.

Paraffin section stained with Bismarck brown.



ENDOTHIA SINGULARIS. VERTICAL SECTION OF A STROMA, SHOWING BOTH PYCNIDIA AND PERITHECIA. $\times 32$.
Paraffin section stained with Bismarck brown.

capable of absorption, a power which it retains relatively permanently." In addition to its absorptive function the entostroma forms the pseudoparenchymatic cover for the perithecial walls.

Ruhland studied herbarium material from the Royal Botanic Museum of Berlin and specimens from Saccardo and Cesati, and described it under the name of *Endothia radicalis* (Schw.) Fr. (*E. fluens* of the present writers). He distinguishes an ectostroma, shaped like a truncated cone, consisting of fine, thin-walled hyphæ, so closely interwoven that the whole structure has a comparatively firm quality. Among these hyphæ are crystals of calcium oxalate. As soon as this ectostroma breaks through the bark there is formed near the middle a short-lived 1-chambered pycnidium. Below this ectostroma (height 0.5 to 0.6 mm., diameter 0.7 to 1 mm.) the entostroma grows out as a mycelium through the upper portion of the bark. Ruhland says, "The entostroma with us does not produce perithecia, but remains wholly mycelial." He studied the perithecial stage in Cesati's specimens, however, and concludes that the perithecia originate without much change in the size of the entostroma and at a considerable distance, about 1 mm., below the ectostroma. The long necks then penetrate through the overlying entostroma and into the ectostroma to the base of the now functionless pycnidia. The upper portion of the ectostroma is then quickly killed and thrown off.

Pantanelli briefly described the stromata of the genus *Endothia*, and pointed out several morphological characters which he considers distinctive of *E. parasitica* in contrast to *E. fluens*. Aside from spore characters, which will be discussed later, Pantanelli (60, p. 870) considers that *E. parasitica* is characterized by numerous stromata, at first embedded in the bark, finally free; by pycnidial cavities numerous and irregularly arranged in various planes in the stromata deep in the bark; pycnidial stromata 1.1 to 1.2 mm. in height and 2.1 to 2.2 mm. in diameter; ascogenous stromata, height 1.8 to 2 mm., length 2.5 to 3.4; width, 3 to 3.2 mm.; perithecia arranged in two or three layers; necks of perithecia averaging 1.25 mm., with inconspicuous ostioles; walls of the perithecia uncolored or light brown.

Endothia fluens, on the other hand, has isolated stromata, chiefly outside the bark; pycnidia aggregated, regularly arranged in a single superficial series; pycnidial stromata, height 0.4 to 0.5 mm., diameter 1.1 to 1.3 mm.; ascogenous stromata, height 1.1 to 1.4 mm., length 2.5 to 3.2 mm., width 1.2 mm.; perithecia arranged in a single row; necks of perithecia averaging 0.45 mm.; ostioles prominent; walls of the perithecia black.

Anderson (1, pp. 17-24) described the development of the fructifications of *Endothia parasitica* in detail. He studied the growth of

the pycnidia in pure culture and made sections of perithecial stromata growing on bark.

According to Anderson, the pycnidium originates as a mass of densely intertwined hyphæ, in the center of which numerous pycnospores are cut off. The crowding of these spores increases the size of the pycnidial cavity and crowds the outer hyphæ together to form a sort of wall. The ostiole is formed in the top by the loosening of the hyphæ. The stroma always starts as a loose growth of hyphæ around the pycnidium. It does not precede, but follows the first stages in the development of that organ. A fluffy growth of light-yellow mycelium surrounds the pycnidium and covers it over. If these are embedded and sectioned, they will be found to contain a loose tangle of undifferentiated hyphæ surrounding a central pycnidium. But as soon as the cork layer is broken the stroma undergoes a change. There is a rapid increase in size and at the same time a differentiation of the cells at the tips of those branches which reach the exposed surface. These cells now become shorter and thicker, acquire heavier walls, and are densely crowded together, so that in cross section they appear as a pseudoparenchymatous tissue. The layer thus formed covers all the exposed surface of the stroma and also grows up around the necks of the perithecia. The stroma increases very rapidly in size and a mass of stromatic tissue is formed beneath the pycnidia, which are thus pushed out through the cork layer into the periphery. The primordia of the perithecia are formed usually in the tissues of the bark below the base of the original pycnidium, but at times are formed well up in the stroma. Usually 15 to 30 perithecia mature in a stroma.

According to the writers' observations, the Tulasnes' description (83, pp. 87-89) is substantially correct so far as it goes. They, of course, placed pycnidial material of *Endothia gyrosa* in the same species with *E. fluens*, but, as already noted, they observed the difference in the structure of the stromata and aptly compared the pycnidial stroma of *E. gyrosa*, as seen in section, to a Gautieria.

The division of the stroma into ectostroma and entostroma made by Ruhland (67, p. 16) has, at least in the species of *Endothia*, no validity whatever. While it is true that pycnidia usually occur in the portion of the stroma first developed and perithecia often develop below them, this is by no means an invariable rule; and while stromata are developed which contain only pycnidia, other stromata apparently produce only perithecia or no spores whatever. Certainly no portion of the stroma can be distinguished which invariably produces only perithecia or only pycnidia. On the contrary, there is great variation in the relative position and time of appearance of the two types of fruiting structures. Also, while

the pycnidial cavity is sometimes small and simple, as described by Ruhland, it is more often large and much convoluted. (See Pls. XV and XVI.)

While the writers, of course, agree with Pantanelli (60) that *Endothia parasitica* and *E. fluens* are distinct species, many of the stromatic characters which he describes are so variable as to be unreliable. In an examination of a large number of specimens the writers have been unable to find any constant difference in the arrangement or structure of the pycnidial stromata. This seems to depend chiefly in both species on the character of the bark and the moisture conditions. As to size, while the stromata of *E. parasitica* examined average somewhat larger than those of *E. fluens*, the range of the pycnidial stromata is about the same in the two species, varying from 0.4 to 2 mm. in height and from 0.2 to 3 mm. in length.

The ascogenous stromata are also very variable in size. Those measured by the writers varied in height from 0.5 to 2 mm. in *Endothia parasitica* and from 0.5 to 2.3 mm. in *E. fluens*. In width the perithecial stromata were from 1 to 2.5 mm. in both species, while there is apparently no method for determining their length, since on thick-barked trees continuous narrow masses of perithecial stromata are often formed in the crevices of the bark. These stromatal masses frequently extend from 5 to 10 cm., and while they are in all probability formed by the fusion of several stromata there is no way of determining how far each extends.

The arrangement of the perithecia mentioned by Pantanelli (60) as a specific character seems to depend on the nature of the bark of the host. When the bark is thin and easily ruptured the stromata tend to spread out so that the perithecia occur in a single layer, while if the bark is thick and deeply ridged the stromata are thicker and the perithecia occur in two or more layers. That this is not a specific character is clearly shown by Plate XVI. Figures 1 and 3 of this plate show a stroma of *E. parasitica* and of *E. fluens*, respectively, both with three layers of perithecia, while Plate XVI, figure 2, and Plate X, figure 1, show stromata of both species with perithecia arranged in a single layer.

Although, as already indicated, the stromata of each species are very variable, they are sufficiently distinct so that the native American species may readily be distinguished in the field.

The stromatic characters of *Endothia gyrosa* and *E. singularis* are much more distinct than those of the other species. The stromata of *E. gyrosa* are erumpent, irregularly subglobose, with a rather roughened surface. They are usually from 1.5 to 2 mm. in height and vary from 1.5 to 3 mm. in width. The stromata of *E. singularis* are much larger than those of any other species of *Endothia*, being

usually from 2 to 4 mm. in length and 3 to 5 mm. or more in diameter. They are decidedly erumpent, rather regular, and subglobose in outline. The contents of the stromata are brick red in color and are very powdery when old.

The stromata of *Endothia fluens*, *E. fluens mississippiensis*, and *E. parasitica* resemble each other so closely that the species are practically indistinguishable on this basis. All these species are characterized by partially embedded, confluent stromata which vary greatly in outline, depending on the nature of the bark of the host. As already stated, they vary from 0.4 to 2 mm. in height and from 0.7 to 5 mm. or more in length where confluent. *E. tropicalis* and *E. longirostris* resemble this group in their stromatic characters.

Pycnidia.—The pycnidia of *Endothia gyrosa* and *E. singularis* are very distinctive also. The pycnidial cavities of *E. gyrosa* are narrow and so irregularly convoluted that in a section of the stroma the cavities vary in width from 0.03 to 0.3 mm., averaging about 0.15 mm. On the whole, however, they are much narrower than those of *E. fluens* or *E. parasitica*. A section of a pycnidial stroma of *E. gyrosa* shows numerous irregular, rounded to elongate chambers separated by narrow walls. The pycnidial cavities of *E. singularis* (Pl. XIII) are minute, 0.03 mm. in diameter, nearly spherical, evenly distributed through the stroma and separated at first by comparatively thick walls, which disintegrate and become powdery when the stroma is old.

So far as the writers have been able to determine, the "tendrils" of pycnosporos so characteristic of *Endothia fluens* and *E. parasitica* are not formed in either *E. gyrosa* or *E. singularis*. Mature pycnidial stromata of *E. gyrosa* when placed in a moist chamber exude numerous droplets containing spores and scattered well over the surface of the stromata. The writers have been unable to produce any such change by placing the pycnidial stromata of *E. singularis* in moist chambers, and it seems probable that the pycnosporos of *E. singularis* are set free by the breaking down of the outer walls of the stromata. As already mentioned, the inner partitions are friable, so the spores are readily scattered by the wind.

The pycnidial cavities of *Endothia fluens* and *E. parasitica*, and apparently all the other species of this section of the genus, vary from 0.2 to 0.3 mm. or more in diameter and may consist of a single chamber rather regular in outline (Pl. XIV, fig. 1) or of an irregular cavity consisting of many chambers (Pl. XV, fig. 3) more or less completely separated from one another. These species differ from *E. gyrosa* in that the pycnosporos are usually discharged through a single opening near the top of the stroma and emerge in a single twisted tendril.

Development of the stromata.—The writers have not followed the development of the stromata in culture, but an examination of numerous sections of *Endothia singularis*, *E. gyrosa*, *E. fluens*, and *E. parasitica* and a study of the three latter species under field conditions on various hosts shows that their development is by no means as uniform as indicated in Anderson's description (1).

According to Anderson, the pycnidium develops first, and about the young pycnidium the stroma is quickly formed, while the perithecia arise later, usually in the lower portion of the stroma. This may perhaps be considered the typical course of development, and pycnidia are often found above the perithecia, but all variations occur. A large stroma may be developed without a sign of a pycnidium (Pl. XV, fig. 2). In some cases there is a considerable portion of the stroma above the pycnidial cavity (Pl. XIV, fig. 2), or the pycnidial cavities may be surrounded by a thick stroma (Pl. XIV, fig. 4, and Pl. XV, fig. 1). Sometimes, on the other hand, they are large and irregular, with little stroma (Pl. XV, fig. 3).

The perithecia by no means uniformly arise below the pycnidia, but the two often occur side by side in the same stroma (Pl. IX, fig. 2; Pl. XIV, fig. 3; and Pl. XII). Sometimes, even, the perithecia are above the pycnidia (Pl. XIV, fig. 2). There seems to be no constant relation either as to the relative number of pycnidia or of perithecia in a single stroma. Sometimes the pycnidial portion is much larger (Pl. IX, fig. 1); sometimes the perithecia predominate (Pl. X, fig. 2); and sometimes the two portions are practically equal (Pl. XII).

A like variability apparently occurs in the sequence of the fruiting bodies. As the figures show, the pycnidia sometimes develop after the perithecia; the reverse order is frequent; while in several sections (Pl. XII, and Pl. XIV, fig. 3) the two types of fruiting bodies were side by side and were producing mature spores abundantly at the same time. Just what factors determine the production of each type of spore or prevent or delay spore production is unknown. It seems probable, however, that climatic influences may prevent the development of ascospores in many cases. The action of climate may be very indirect, however, for no ascospores of any species have yet been obtained in artificial cultures, though *Endothia fluens*, *E. fluens mississippiensis*, *E. tropicalis*, and *E. parasitica* produce pycnospores abundantly on a variety of media. Certainly, climatic factors would not account satisfactorily for the fact that pycnidia and perithecia are produced at the same time in adjacent stromata, or even in different parts of the same stroma.

The size of the perithecia is rather uniform in the various species (Pl. X, fig. 3, and Pls. XI and XVI), being about 0.35 mm. in diameter. They are typically globose to pyriform, but are usually more or

less irregular on account of crowding. This pressure may be so great as to produce almost any shape, and such perithecia sometimes measure 0.5 mm. in the greatest diameter and 0.1 mm. in the shortest.

SPORE MEASUREMENTS.

The spore measurements recorded here were made by Miss Tiller. In the case of dried specimens, the spores were first soaked for three hours in lukewarm water and then mounted in the potassium-glycerine-copper medium, prepared according to the following formula:

1 part 2 per cent potassium acetate in water.

1 part 40 per cent glycerine in alcohol.

Copper acetate sufficient to color.

In the case of fresh specimens they were mounted directly in the same medium. The measurements were made with a Zeiss filar eyepiece micrometer and a Zeiss 3 mm. 1.40 N. Ap. oil-immersion objective. Only approximate accuracy is claimed for these results, on account of the difficulty of overcoming the motion of the spores in a fluid medium. The results are, however, believed to be fairly comparable, as practically all were measured under the same conditions and treatment, and the margin of error is presumably rather uniform. The differences in size of pycnospores do not appear to be sufficient, however, to furnish diagnostic character for most of the species.

The number of measurements of ascospores of *Endothia fluens* and *E. parasitica* is much larger than of the other species, as special attention was first given to these two species on account of their great similarity. In order to make the measurements of these species comparable to the others, the total number of spores of each length has been calculated in the percentage of the total number of spores measured.

METHOD OF TABULATION.

For better comparison, the spore measurements have been tabulated by half microns, all the spores in each specimen coming within 0.2 of a micron of each unit or half being grouped together; e. g., all the spores having a length of 7.3, 7.4, 7.5, 7.6, and 7.7 microns are included under the heading 7.5. The tables thus show at a glance the number of spores of a given length per specimen. The widths have been tabulated in the same way.

For a better comparison of the shapes of the ascospores of *Endothia parasitica* and *E. fluens*, the relative ratios of length to width in each spore have been calculated, the width being considered unity. The ratios of length to width were then tabulated by tenths; that is, all the spores in each specimen having a ratio of length to

width from 1.76 to 1.85 microns are included under 1.8. The relative shapes of the spores in each specimen are thus clearly shown.

TABLE I.—*Measurements of pycnospores and asci of Endothia.*

PYCNOSPORE MEASUREMENTS.

Specimens.	Number per specimen having the given length or width.																Total.
	Lengths (microns).												Widths (microns).				
	2	2.5	3	3.5	4	4.5	5	5.5	6	6.5	7	1	1.5	2	2.5		
Sphaeria gyrosa Schw., Herb. Mus., Paris.....	2	3	6	11	4							9	15	2		26	
S. gyrosa Schw., Herb. Schwaeg.			5	9	3							5	11	1		17	
Endothia gyrosa on beech, Alcorn, Miss., No. 1796.....			10	11	3							5	18	1		24	
E. singularis, No. 1939.....			4	6	4								5	9		14	
E. fluens, Sowerby.....				8	11	6							8	17		25	
E. fluens on chestnut, Fort Payne, Ala.....			1	6	12	5	1						6	19		25	
E. fluens, Lugano, Switzerland.			1	3	5	2	1						8	4		12	
E. fluens mississippiensis, No. 1706A.....			2	5	8	1							7	9		16	
E. longirostris.....	2	3	4	4	1							6	8			14	
E. tropicalis.....				2	5	6	3	3	2		4		3	19	3	25	
E. parasitica, No. 1696.....			1	6	11	6	1						12	13		25	

LENGTHS OF ASCI (MICRONS).

Specimens.	No.	Number per specimen having the given length.								Total.
		25	30	35	40	45	50	55	60	
<i>Endothia fluens</i> on Castanea.....	1702	2	8	11	1					22
Do.....	1737		1	14	11					26
Do.....	1741		5	6						11
Do.....	1729		4	16	6					26
<i>E. fluens</i> on dead Castanea.....	1715		7	16	3					26
<i>E. fluens</i> on Castanea, Stresa, Italy.....	1656		6	16	1	1	1			25
<i>E. fluens</i> on Quercus.....	1711	2	16	7						25
Do.....	1927	2	10	12						24
<i>E. fluens mississippiensis</i> , Blue Mountain, Miss.....	1806		5	14	3					22
<i>E. parasitica</i> on Castanea.....	1710		1		1	2				4
Do.....	1739			5	10	10	1			26
<i>E. parasitica</i> , China.....	2151				2	14		4	3	27
<i>E. gyrosa</i> on Quercus.....	1709	1	7				4			8
<i>E. gyrosa</i> on Liquidambar.....		19	6							25
<i>E. singularis</i> , Palmer Lake, Colo.....		4	15	5						24
<i>E. longirostris</i> , Porto Rico.....		6	13	3	3					25
<i>E. longirostris</i> , French Guiana.....		6	10	1						17
<i>E. tropicalis</i>						6	5	3	2	16

WIDTHS OF ASCI (MICRONS).

Specimens.	Number per specimen having the given width.							Total.
	4	5	6	7	8	9	10	
<i>Endothia gyrosa</i>			8	2				10
<i>E. singularis</i>	1	8	2					11
<i>E. fluens</i> , Europe.....			2	6	4			12
<i>E. fluens</i> , America.....			1	6	4			11
<i>E. fluens mississippiensis</i>			2	6	2			10
<i>E. longirostris</i> , Porto Rico.....		2	7	2				11
<i>E. longirostris</i> , French Guiana.....			3	3	3			9
<i>E. tropicalis</i>				2	6	2		10
<i>E. parasitica</i> , China.....				1	7	2		10
<i>E. parasitica</i> , America.....					6	4		10

PYCNOSPORES.

The pycnospores of all the species are oblong elliptic to cylindric in shape and so small as to make accurate measurement very difficult. Slight but apparently constant differences in their size in certain groups of species may, however, be traced. These differences are clearly shown in Table I.

Endothia gyrosa, *E. singularis*, and *E. longirostris* have smaller pycnospores than the other species, the most frequent lengths being 3 and 3.5 μ . The pycnospores of *E. singularis* are slightly broader than those of *E. gyrosa* and *E. longirostris*, being 1.5 to 2 μ , as against 1 to 1.5 μ in the last two species.

Endothia fluens, *E. fluens mississippiensis*, and *E. parasitica* are even more closely similar in the size of their pycnospores than in that of their ascospores, the most frequent size being 4 by 2 μ . The pycnospores of *E. tropicalis* are much larger and more variable in size and shape than those of other species. They range from 3.5 to 7 μ in length and from 1.5 to 2.5 μ in width.

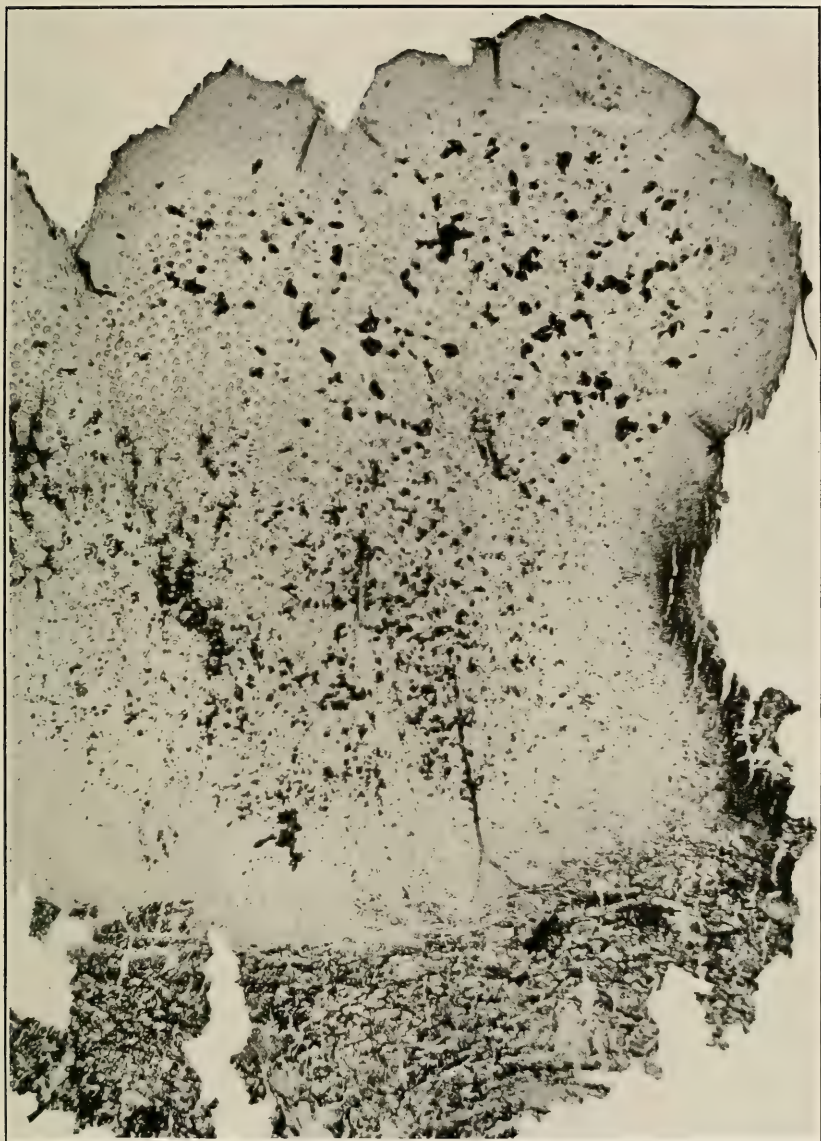
ASCI.

The writers have not attempted a study of the origin and early development of perithecia or asci in any of the species of *Endothia*. Work on this subject has been published by Anderson and Rankin (6), for *Endothia parasitica*, but the nuclear phenomena and origin and development of the ascogenous hyphæ are not yet entirely clear. The part termed a trichogyne by these authors seems more likely to be the initial stage in the development of the neck of the perithecium than the relic of an organ of fertilization.

The asci appear almost or quite sessile in most species, and though varying considerably in size and shape, as indicated in Table I, are usually oblong elliptic or subclavate, having a sort of inner membrane inclosing the ascospores and some thin granular matter extending to the apex of the ascus, where a slight thickening appears, as described and illustrated by Anderson for *Endothia parasitica*. A similar condition is found in various species of *Pyrenomycetes* and probably functions in some way in connection with the discharge of the ascospores. The asci are generally wider and slightly longer in *E. parasitica* than in *E. fluens* and other members of section 2. The asci of *E. gyrosa* are shorter than those of any other species. *E. tropicalis* has the longest asci. The asci of none of the species show a very wide range of variation, as Table I also indicates.

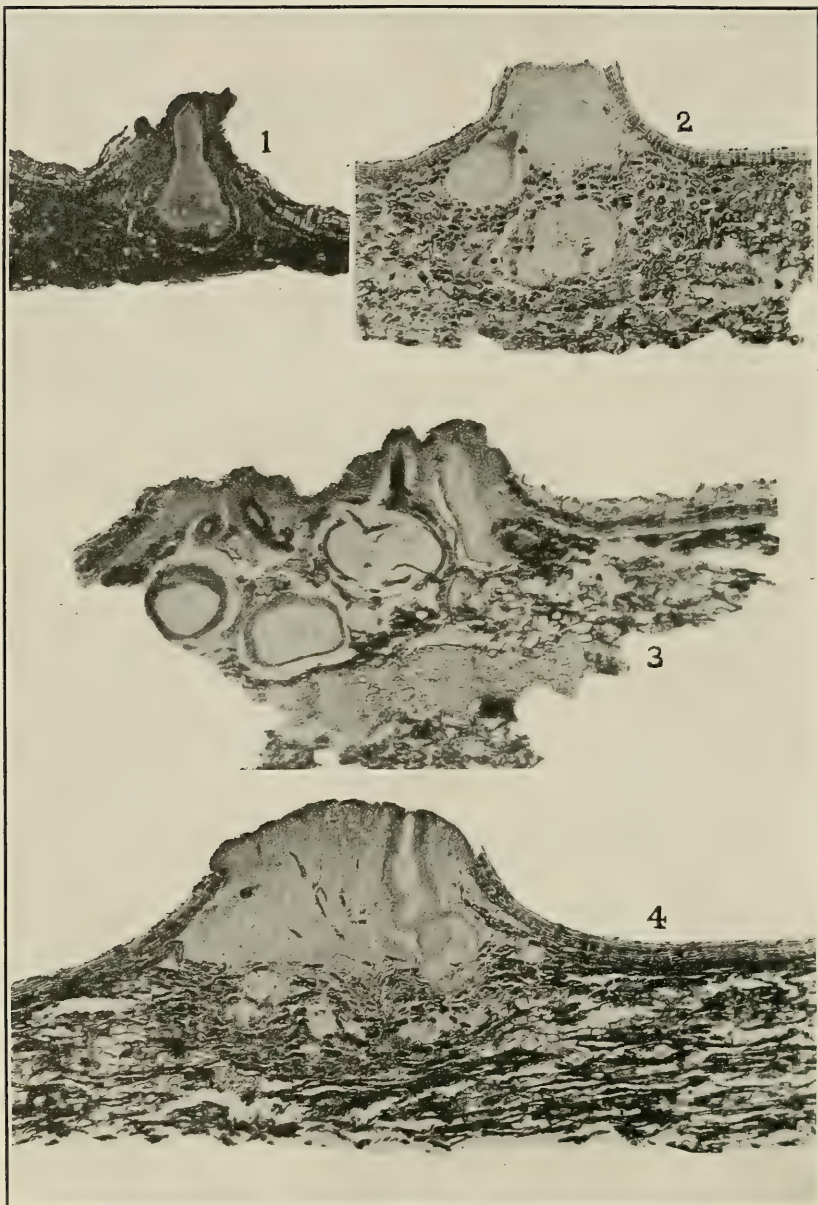
PARAPHYSES.

Most students of *Endothia* have reported paraphyses wanting in this genus. Anderson (1, p. 33, fig. 32) and Anderson and Rankin (6, p. 579, fig. 83) report paraphyses present and figure what they



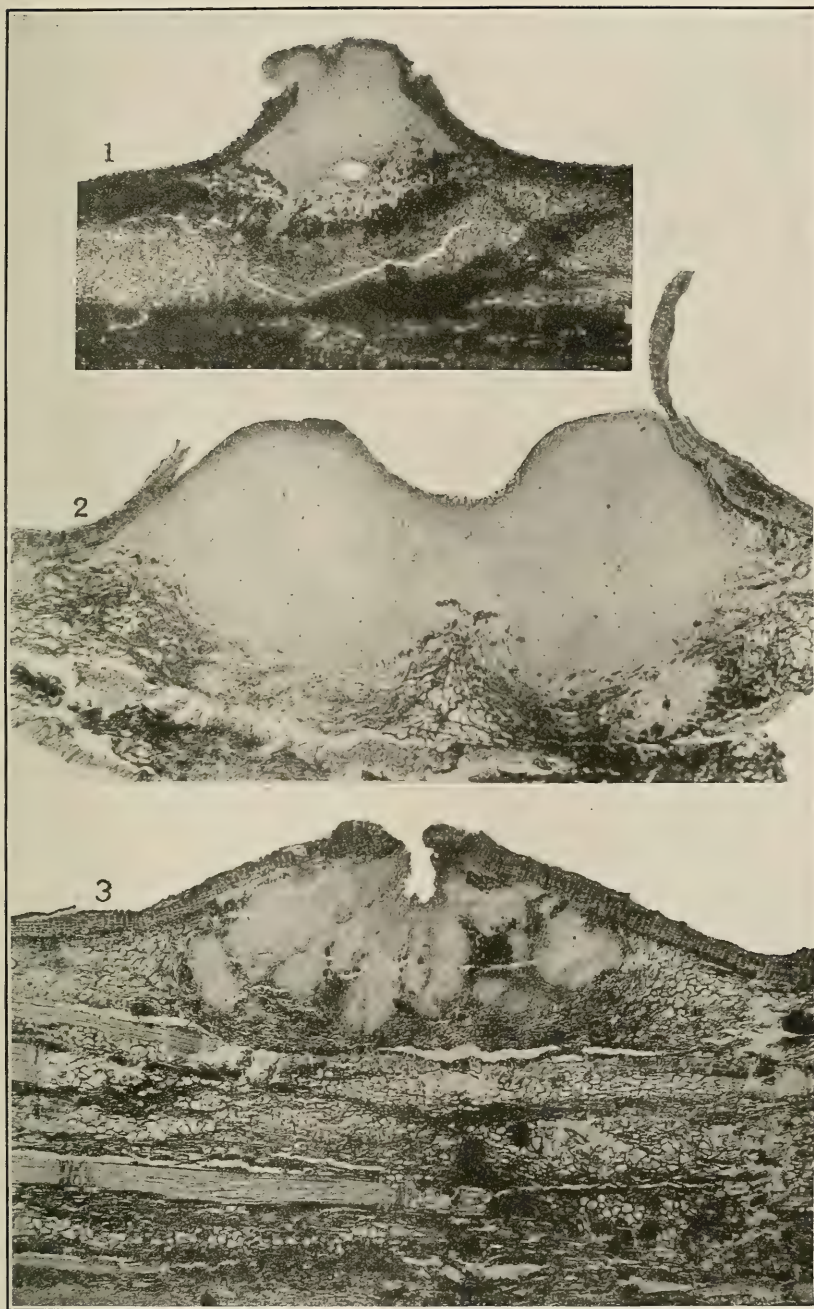
ENDOTHIA SINGULARIS. VERTICAL SECTION OF THE MAJOR PART OF A PYCNIDIAL STROMA. $\times 32$.

Paraffin section stained with Bismarck brown.



ENDOTHIA FLUENS. VERTICAL SECTIONS. $\times 49$.

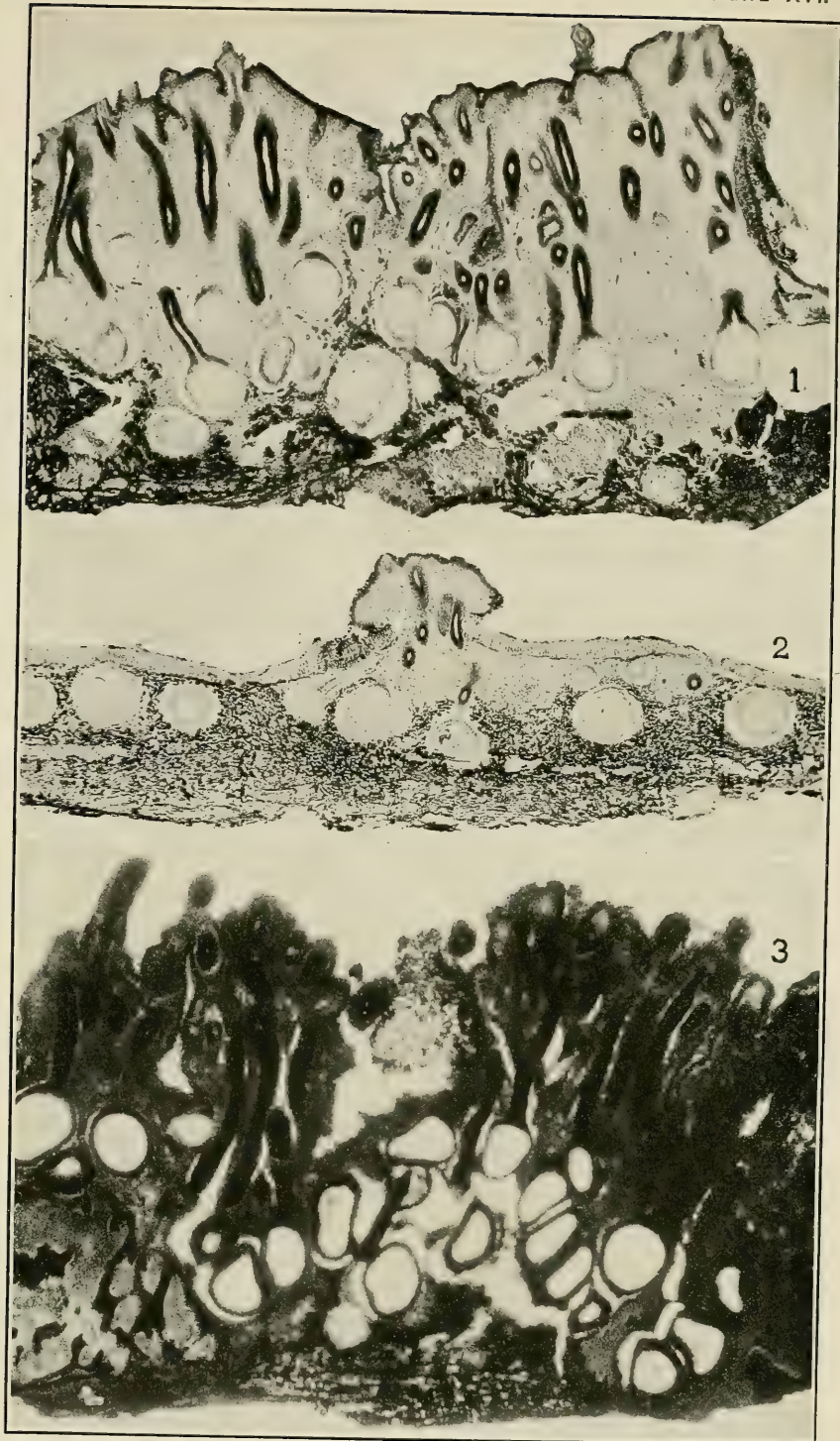
FIG. 1.—SIMPLE PYCNIDIUM WITH VERY LITTLE STROMA, FROM ITALY. FIG. 2.—STROMA FROM ITALY, SHOWING A PERITHECIUM ABOVE A PYCNIDIUM. FIG. 3.—STROMA FROM AMERICA, SHOWING A MATURE PYCNIDIUM AND PERITHECIA SIDE BY SIDE. FIG. 4.—STROMA, SHOWING A SINGLE PYCNIDIUM AND FUNDAMENTS OF PERITHECIA BELOW.



ENDOTHIA PARASITICA. VERTICAL SECTIONS OF STROMATA. $\times 49$.

FIG. 1.—SHOWING A YOUNG, SIMPLE PYCNIDIAL CAVITY AT THE BASE. FIG. 2.—IN WHICH NEITHER PYCNIDIA NOR PERITHECIA HAVE BEGUN TO DEVELOP. FIG. 3.—WITH IRREGULAR CHAMBERED PYCNIDIA.

All the above are about the same age—four months after inoculation.



ENDOTHIA PARASITICA AND E. FLUENS. VERTICAL SECTIONS OF STROMATA. $\times 20$.

FIG. 1.—*E. PARASITICA*. SHOWING PERITHECIA ARRANGED IN SEVERAL IRREGULAR LAYERS. FIG. 2.—*E. PARASITICA*, SHOWING PERITHECIA ARRANGED IN A SINGLE LAYER. FIG. 3.—*E. FLUENS*, FROM ITALY, SHOWING PERITHECIA ARRANGED IN SEVERAL LAYERS.

regard as an early stage of their development. They describe them as branching frequently and very crooked, extending around the perithecium as well as upward. The writers have searched in all the species studied for evidence of the presence of paraphyses, but have never seen anything resembling paraphyses as they occur in closely related Pyrenomycetes. If they occur, they would seem to be of an unusual character and difficult to recognize or else are evanescent, disappearing before the asci are mature.

ASCOSPORES.

The ascospores furnish one of the most marked characters for the separation of the genus into sections (Plate XVII). In section 1 they are more or less cylindric and sometimes curved. In section 2 they are more or less elliptic, being broadest in *Endothia parasitica* and narrowest in *E. fluens* and *E. longirostris*. The greatest variation in size and shape of ascospores occurs in *E. fluens*, as indicated by the measurements given in Table II. Anderson (1), Clinton (18), and Heald (39) describe and figure the ascospores of *E. parasitica* as very obtuse and constricted at the septum. The writers have but rarely seen spores of this form. This may perhaps be due in part to different methods of treatment or to the age and condition of the material. Most of the ascospores studied by the writers have been mounted in the fluid medium described on page 30. Fresh specimens have also been studied in water mounts, but with the same general result. The writers are of the opinion, therefore, that the figures of the authors cited above do not represent the most common and characteristic form of ascospores of this species. (Compare Plate XVII, figs. 7 to 15.)

Endothia tropicalis:		3	9	22	35	20	9	2											5	43	43	9	100		
Ceylon		2	9	17	35	20	13	4											1	28	50	21	100		
Do.																									
E. parasitica:																									
On Castanea sp., Santun- ying, China On Castanea dentata— From Pantanelli ¹ Gordonsville, Va. Odonton, Md.	2151	8	17	18	26	18	8	3	1	1											6	27	52	15	100
	1658	3	8	15	19	21	15	7	4	3												17	39	39	95
	1739	7	17	16	32	21	10	7	3	1												3	59	9	114
	1710	3	20	23	38	6																13	74	6	93
	Total.		18	45	69	103	98	39	17	8	5											9	100	224	69	402
Per cent.			1.1	1.7	25.6	24.4	10.0	0.4	0.2	0.1											0.2	24.9	55.8	17.2	
Specimens.		No.	1.6	1.7	1.8	1.9	2	2.1	2.2	2.3	2.4	2.5	2.6	2.7	2.8	2.9	3	3.1	3.2	Total.					
Sphaeria radialis, Fries's herbarium																				91					
Endothia fluens:																									
North Carolina.		1729																							
Do.		1715		2	3	16	8	8	16	15	8	6	4	3	5	2	1	1		98					
Pennsylvania.		1702		1	4	10	12	12	24	14	8	7	3	3	2	2	1			95					
Virginia.		1741			2	4	10	12	10	7	9	13	13	7	6	2	2	1		99					
Do.		1927		1	6	16	16	12	13	3	3	1	1							71					
Do.		1737			4	15	18	16	7	14	11	6	3	4			1			99					
Total, American.				4	22	67	75	72	79	65	54	44	31	20	13	6	5	3		560					
Per cent.				0.7	3.9	12.0	13.4	12.9	14.1	11.6	9.7	7.9	5.5	3.6	2.3	1.1	0.9	0.5							
Endothia fluens:																									
Stresa, Italy.		1656			5	4	11	23	13	12	13	1	6	4	3	3	2		1	101					
Como, Italy.		1637					1	7	8	12	10	11	20	12	9	4	2	2		98					
Do.		1655				2	3	11	12	12	17	12	13	7	5	2	1	2	1	100					
Total, European.					5	6	15	31	33	36	40	24	39	23	17	9	5	4	2	299					
Per cent.					1.7	2.0	5.0	13.8	11.1	12.1	13.4	8.0	13.1	7.7	5.7	3.0	1.7	1.4	0.7						
Endothia parasitica:																									
On Castanea sp., Santunying, China.		2151		11	17	33	22	9	3	2	1									100					
From Pantanelli ¹		1658	2	8	16	29	23	8	8											95					
Gordonsville, Va.		1739		10	18	31	24	12	6	3	2	1	4	1	2					114					
Odonton, Md.		1710		1	14	37	25	12	3	1										93					
Total.			4	30	65	130	94	41	20	7	3	1	4	1	2					402					
Per cent.			1	7.5	16.2	32.4	23.4	10.0	5.0	1.7	0.7	0.2	1.0	0.2	0.5										

¹ Specimens of American material sent by Pantanelli, of Rome, Italy.

PHYSIOLOGY.

CULTURAL STUDIES.¹

During the past three years the writers have had under observation more than 4,000 cultures of the several species of *Endothia* on more than a dozen artificial media, as well as on sterilized twigs of many kinds. Throughout this work the writers have been impressed with the uniformity of the behavior of the organism in culture and the certainty with which the various species could be distinguished on any of the media used.

Cultures of *Endothia parasitica*, for instance, from specimens sent from China or British Columbia were absolutely indistinguishable from cultures made on the same medium from local material. Transfers made from stock cultures which had been kept on artificial media for two years were identical with transfers from freshly collected material. The same remarkable constancy held for the other species. Cultures from material collected in different localities or from different hosts were identical, not only in appearance but, so far as the writers were able to determine, in temperature and moisture relations also. As previously noted, this is in marked contrast to the senior writer's experience with the species of *Glomerella* and it is believed differs from the experience of many investigators of fungi.

No less striking is the certainty with which the several species may be distinguished on any medium tried. *Endothia parasitica*, *E. tropicalis*, and *E. fluens* and its variety *mississippiensis* are very closely related morphologically. Moreover all except *E. parasitica* have, as near as could be determined, much the same relation to their hosts. Yet each species has distinctly and readily recognized characters on culture media.

It should not be imagined, however, that the differences are recognizable at once as clearly distinctive characters. The differences at first glance might readily be considered fluctuating variations. But the fact that the characters remain constant through hundreds of generations and have never varied toward one another makes them worthy of recognition as specific characters.

In a previous paper (77) the writers described their results with cultures of *Endothia parasitica*, *E. fluens*, *E. fluens mississippiensis*, and *E. gyrosa* on a number of culture media. At that time the work of other investigators was reviewed and the methods of preparing the various culture media and making the cultures described. Since the publication of that paper, however, cultures of two more species, *E. tropicalis* and *E. singularis*, have been secured and about 2,000 additional cultures of the various species made. In addition to the culture media mentioned in the previous paper (77, p. 10), the writers

¹ The cultures described were all grown at ordinary laboratory temperatures in the winter, about 20° to 24° C.

have grown the organisms on sterile twigs of many species and on liquid media.

As stated above, the various species of *Endothia* are distinguishable on any medium tested. White corn meal in flasks has, however, been most used by the writers in identification work and for keeping stock cultures. All the species grow readily on this medium and may be determined with certainty within 10 days under ordinary conditions of growth. In addition, the medium is cheap, easily prepared, and does not dry out so quickly as agar media in tubes, so cultures may be kept alive much longer without transfers. Almost equally good for purposes of identification are rice and oatmeal in flasks, corn-meal agar, and potato agar.

The distinguishing characteristics of the various species in culture have been described rather fully in the previous publication and may be briefly summarized, as follows:

CULTURES ON CORN-MEAL AGAR (UNSLANTED TUBES).

Corn-meal agar proved the best agar medium for the production of pycnospores and showed constant differences in the cultural characters of the various species. The most characteristic differences appeared in cultures from six to eight weeks old on unslanted tubes. (See Pl. XXI, figs. 2 to 7.)

Endothia gyrosa at this age showed a rather abundant, felty white mycelium, flecked with capucine buff, but there were no pycnidia. In older cultures small pycnospore threads were sometimes produced. Usually before the cultures were 10 days old the medium was changed to a delicate lavender just below the mycelium, and below this to a light olive green. A few days later the lavender disappeared and the green deepened to olive green.

Endothia singularis grew more slowly than any other species. Within three weeks, however, the mycelium covered the entire surface. It was smoother than *E. gyrosa* and nearly white, with raw umber spots where the mycelium touched the glass. The medium was changed to a light hellebore green one-half inch below the top.

Endothia fluens, as pointed out in the previous paper, produced an abundant deep-chrome mycelium, with usually one or two rather small pycnidial pustules.

Endothia fluens mississippiensis produced a scant surface growth of mycelium, between cadmium yellow and raw sienna in color. The upper one-half centimeter of the agar became reddish orange. The pycnidial pustules were more numerous than those of *E. fluens*, but smaller and more scattered than those of *E. parasitica*.

Endothia longirostris at the end of six weeks had a scant, webby, orange, aerial mycelium growing against the glass. Mycelium on the surface of the medium was very scant, orange to cadmium yellow in color, with scattered tiny xanthine orange to orange spore masses. The color of the agar changed to medal bronze just beneath the mycelium, shading into orange citrine below.

Endothia tropicalis at the end of six weeks showed a thinly felted mycelium, white to capucine orange, with numerous small, scattered pycnidial pustules. The ring of mycelium against the glass was light orange yellow, as contrasted with white in *E. parasitica*.

Endothia parasitica gave a scanty white growth of surface mycelium, with several prominent pycnidial pustules clustered near the center and of a slightly darker shade than the "raw sienna" of Ridgway.¹

CULTURES ON POTATO AGAR (SLANTED TUBES).

Potato agar was used by the Andersons (3) to distinguish *Endothia parasitica* from *E. fluens*. The writers have used it extensively and found it a very useful medium for distinguishing the species. As stated in the previous paper (77, p. 11), however, unless this medium was very carefully prepared it varied greatly in acidity and probably in other respects, with resultant variations in the behavior of the organisms. Spore production was not so abundant on this medium as on many others. The preparation of this and other media is described in the paper cited.

Endothia gyrosa.—This species developed rather slowly, producing a fairly abundant aerial growth, which was felt rather than fluffy. The color was white, flecked with capucine buff, and no spore masses were produced.

Endothia singularis.—This species grew even more slowly than *E. gyrosa*. On cultures made from conidia, growth was hardly perceptible at the end of three days. Mycelial cultures at the end of one week showed less growth than *E. gyrosa*, but did not differ greatly from it in either color or texture. At the end of one month the mycelium was slightly more fluffy and decidedly less in amount than that of *E. gyrosa*. Most of the surface was a very light buff color, with sometimes a few spots of capucine orange to English red.

Endothia fluens.—Pycnospore streak cultures of this species varied somewhat as to the amount and time of appearance of color, probably due to the variations in the acidity of the medium referred to above. Many tubes showed an orange color in one week, while others produced no orange whatever. In no case did cultures of *E. fluens* produce the "brassy" metallic surface appearance so characteristic of *E. parasitica*. Pycnidia were few and more scattered than in *E. parasitica* and did not begin to appear until the third or fourth week. A slight amount of warbler-green color sometimes appeared in the medium at this age, but never so conspicuously as in *E. parasitica*.

Endothia fluens mississippiensis.—This produced a less fluffy aerial mycelium along the spore streak than *E. parasitica*. After five or six days the fungus showed an orange color by transmitted light, and was indistinguishable in this respect from *E. parasitica*. The character of the surface was somewhat different, however, and by reflected light appeared xanthine orange. When two weeks old this form differed still more markedly from *E. parasitica* in color, being grenadine red by transmitted light and showing no spore masses.

E. longirostris.—At the end of one week this produced a white, fluffy growth scattered in small patches over the surface of the medium. This later became rather close in texture, especially near the base of the agar slant. No spores were produced on this medium.

Endothia tropicalis.—At the end of one week this showed less growth than *E. fluens*, covering about a third of the surface of the medium, while the other covered nearly the entire surface. The mycelium was closely matted and a very pale buff (paler than any in Ridgway). At the end of one month

¹ In the descriptions of cultures comparisons were necessarily made with cultures in flasks or tubes. This of course made comparison more difficult and somewhat less accurate than if the material had been removed from the container.

E. tropicalis covered the entire surface with a thin layer of surface mycelium, considerably darker in color than when one week old.

Endothia parasitica.—At the end of three or four days at room temperature this showed a short, fluffy, white, aerial growth along the streak. The surface of the mycelium was orange by transmitted light, while by reflected light it was between raw sienna and antique brown at the sides. Within six days the mycelium, especially at the base of the agar slant, took on a peculiar metallic "brassy" appearance, due apparently in part to the character of the mycelium and in part to the minute water drops scattered over the surface. This portion of the culture was light orange yellow by reflected light and orange by transmitted light. This metallic appearance has been found to be the most constant and reliable distinguishing character of *E. parasitica* on potato agar. In 12 to 14 days small pycnidial pustules appeared in the upper portion of the tubes, and the agar just below the mycelium became warbler-green, changing later to olive green.

CULTURES ON CORN MEAL (IN 100 C. C. ERLNMEYER FLASKS).

Endothia gyrosa.—Mycelial cultures one week old showed a growth of rather compact mycelium covering nearly one-half the surface of the medium. The mycelium was ochraceous buff near the point of inoculation, shading into white at the margin. There was no discoloration of the medium and no spore masses were seen.

Cultures of the same kind one month old showed an abundant, rather thick growth, having the surface mostly covered with somewhat irregular tubercular masses, suggesting immature pycnidial stromata similar to those found in *E. radicalis*, but smaller and producing no spores. The surface of the culture was capucine buff, that of the tubercles honey yellow to Isabella. The dark color was apparently due in part to numerous superficial water drops. A portion of the medium was changed to perilla purple.

Endothia singularis.—Mycelial cultures one week old covered only one-third of the surface. The growth was mostly white and fluffy, with ochraceous buff near the center.

At the end of one month the growth had entirely covered the surface. The mycelium varied in color from cadmium orange to capucine buff, the color being distributed over the surface in patches. The corn meal was changed to perilla purple near the center. No spores were produced.

E. singularis was readily distinguishable from *E. gyrosa*, which it resembled more closely in culture than any of the other species, by the rate of growth and the color and nature of the surface of the mycelium. *E. singularis* grew more slowly than *E. gyrosa*, was rather brighter in color (cadmium orange), and the surface of the mycelium was decidedly more even, lacking the tubercular masses characteristic of *E. gyrosa*.

Endothia fluens.—Cultures at the age of one week showed a growth of loose, fluffy mycelium covering one-half of the surface of the medium. The mycelium was deep chrome to light orange yellow at the point of inoculation, passing through perilla purple and light pinkish lilac and fading into white at the margin. Occasionally the medium was changed to perilla purple near the center. No spores were present.

Cultures one month old showed a compact growth, with a nearly smooth surface. The color ranged from light cadmium to empire yellow. The whole mass of the medium was perilla purple. Spore masses were rarely present at this stage, but shortly afterwards a few large erumpent stromata were formed, which extruded spores in thick masses.

Endothia fluens mississippiensis.—Cultures one week old showed an orange-chrome growth a little more than half covering the surface of the medium. The superficial growth was very similar to that of *E. parasitica*. There was no discoloration of the medium and no spore masses were found.

The same organism one month old produced a growth with a compact, rather uniform surface, the superficial portion having a coarse, matted, webby appearance, which was most noticeable about the margin. The color of the mycelium was cadmium orange to xanthine orange, while that of the medium was unchanged. Spore masses were much more numerous than in *E. fluens*, but smaller and less numerous though very similar to those of *E. parasitica*.

E. longirostris.—Cultures one week old covered about one-third of the surface of the medium. The mycelium was short, fluffy, white, with only a tiny spot of cadmium orange near the point of inoculation. At the end of six weeks the entire surface was covered with a compact growth rather uniform in texture, cadmium orange to xanthine orange in color. The surface was irregularly ridged, giving it a wrinkled appearance, with tiny mars orange spore masses irregularly scattered over the surface. This species closely resembles *E. fluens mississippiensis* on this medium, being distinguished from that variety by the smaller and much less numerous spore masses. The medium is changed to amber brown just below the mycelium, shading into mars yellow in the lower portions.

Endothia tropicalis.—At the end of one week this showed less growth than either *E. parasitica* or *E. fluens*, covering about a third of the surface. The mycelium was matted close to the surface and was a very pale buff (paler than any of the buffs shown in Ridgway). No pycnidia were present.

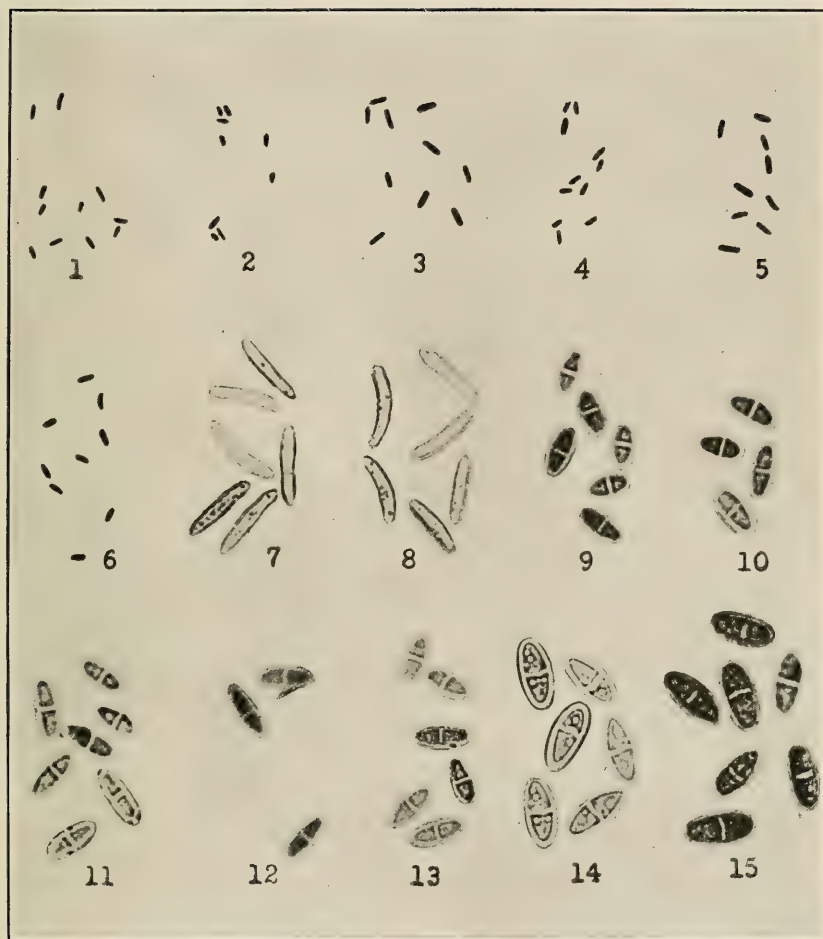
At the end of one month's growth the surface was entirely covered with a closely felted mycelium and small, numerous, thickly scattered spore masses, more closely resembling those of *Endothia parasitica* than any other species. The mycelium was orange buff to apricot orange, and orange chrome against the glass. The color of the medium was unchanged.

Endothia parasitica.—In cultures one week old the growth on corn meal covered about one-half of the surface of the medium. The outer margin was pure white, the remainder buff yellow below, with a superficial white growth above. A few small pustules with spore masses occurred near the point of inoculation. The medium was uncolored.

Cultures one month old showed a compact growth, nearly smooth on the surface. The superficial mycelium was pale orange yellow. The pale yellow-ocher spore masses were minute, very numerous, and nearly covered the surface. The medium was slightly greenish about the sides of the flask just beneath the mycelium.

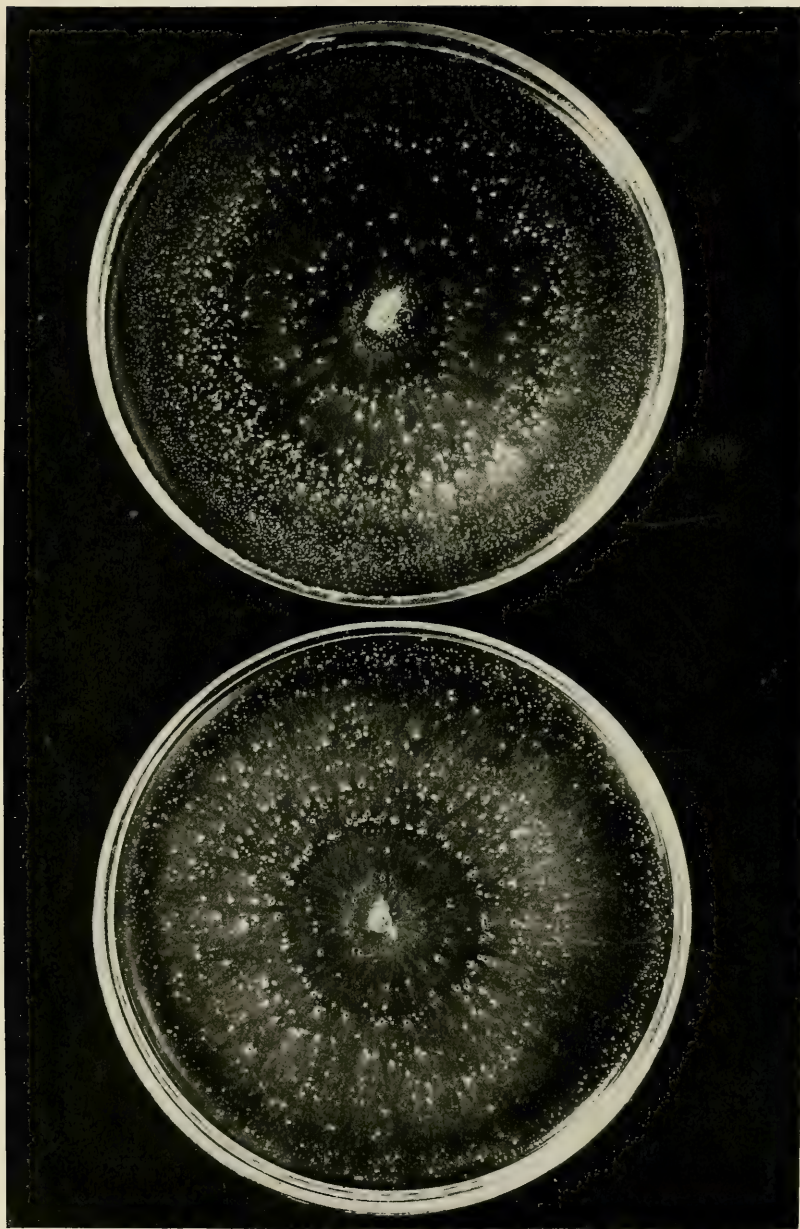
DISTINGUISHING CHARACTERS OF THE VARIOUS SPECIES ON CORN MEAL IN FLASKS.

The color reactions of the various species on corn meal are very striking. *Endothia fluens* (Pl. XXI, fig. 1b), as noted above, changes the whole mass of the medium to perilla purple in less than a month. *E. gyrosa* and *E. singularis* also produce this color change, but somewhat more slowly. *E. fluens mississippiensis*, *E. tropicalis*, and *E. parasitica*, on the other hand, in hundreds of cultures have wholly failed to produce any purple color. This furnishes an easy and reliable method of distinguishing *E. parasitica* from *E. fluens*

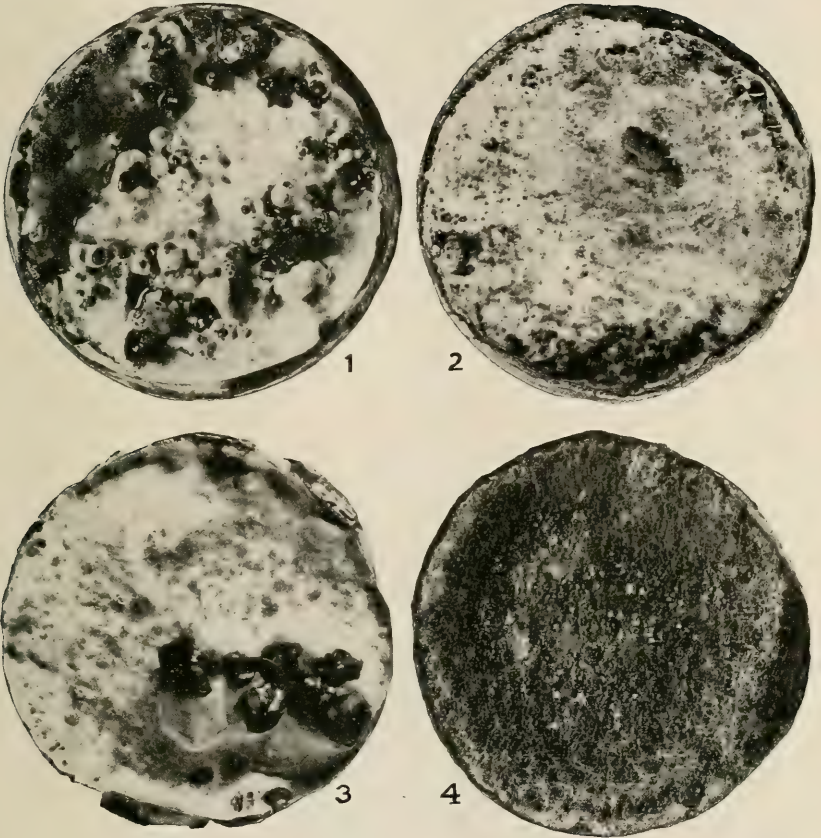


PHOTOMICROGRAPHS OF PYCNOSPORES AND ASCOSPORES OF
ENDOTHIA.

FIGS. 1 TO 6.—PYCNOSPORES: 1, *ENDOTHIA GYROSA*; 2, *E. SINGULARIS*; 3, *E. FLUENS*; 4, *E. LONGIROSTRIS*; 5, *E. PARASITICA* (AMERICAN); 6, *E. PARASITICA* (CHINESE).
FIGS. 7 TO 15.—ASCOSPORES: 7, *E. GYROSA*; 8, *E. SINGULARIS*; 9, *SPHAERIA RADICALIS*, FROM SCHWEINITZ'S SPECIMEN IN FRIES'S HERBARIUM; 10, *ENDOTHIA PSEUDORADICALIS*; 11, *E. FLUENS*; 12, *E. FLUENS MISSISSIPPIENSIS*; 13, *E. LONGIROSTRIS*; 14, *E. TROPICALIS*; 15, *E. PARASITICA*.

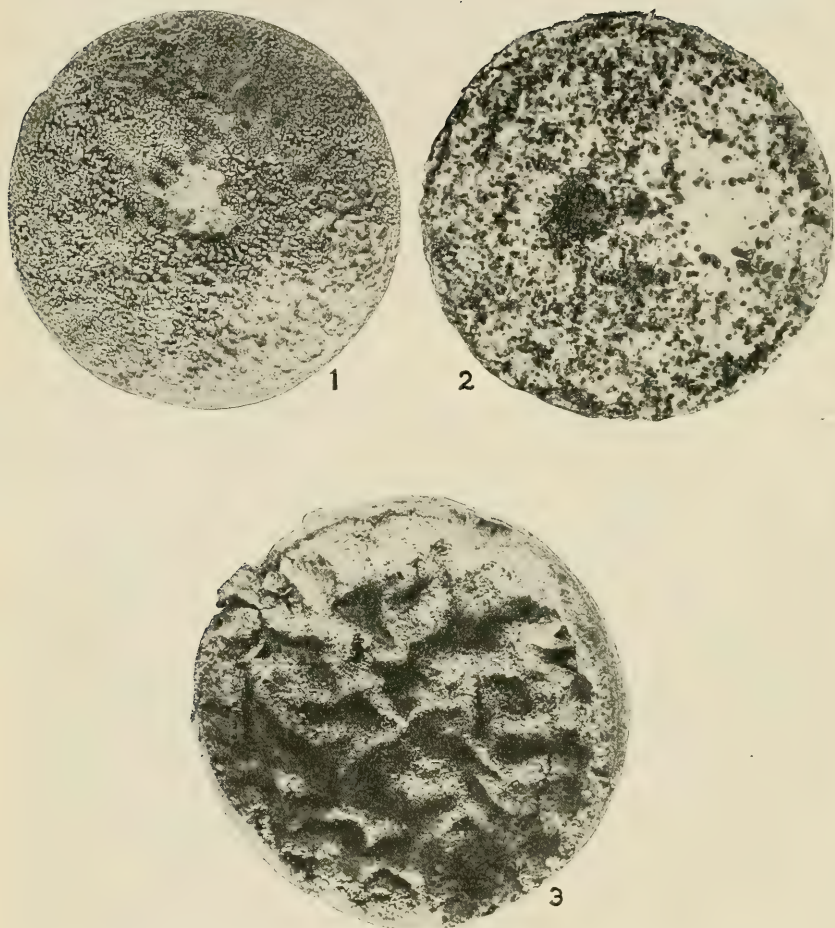


ENDOTHIA PARASITICA ON PLATE CULTURES OF CORN-MEAL AGAR 4 WEEKS OLD. THE UPPER PLATE WAS KEPT IN TOTAL DARKNESS; THE LOWER PLATE IN THE DIRECT LIGHT OF A NORTH WINDOW.



ENDOTHIA SPECIES ON WHITE CORN MEAL (10 GRAMS OF CORN MEAL TO 20 C. C. OF WATER). CULTURES 2 MONTHS OLD.

FIG. 1.—*ENDOTHIA GYROSA*; FIG. 2.—*E. SINGULARIS*; FIG 3.—*E. FLUENS*; FIG. 4.—*E. FLUENS MISSISSIPPIENSIS*.



ENDOTHIA SPECIES ON WHITE CORN MEAL (10 GRAMS OF CORN MEAL TO 20 C. C. OF WATER). CULTURES 2 MONTHS OLD.

FIG. 1.—*ENDOTHIA TROPICALIS*; FIG. 2.—*E. PARASITICA*; FIG. 3.—*E. LONGIROSTRIS*.



M.S. Haffley

CULTURES OF ENDOTHIA SPECIES

FIG. 1.—*a*, Corn meal after 1 month's growth of *Endothia parasitica*; *b*, corn meal after 1 month's growth of *E. fluens*.

Typical cultures on upright tubes of corn-meal agar 6 weeks old. FIG. 2.—*E. grossa*. FIG. 3.—*E. singularis*. FIG. 4.—*E. fluens*. FIG. 5.—*E. fluens mississippiensis*. FIG. 6.—*E. tropicalis*. FIG. 7.—*E. parasitica*.

(Pl. XXI, fig. 1) in field work when fructifications of the species are wanting or doubtful.

Aside from the differences in color, the most conspicuous and important characteristic of these fungi in corn-meal cultures is found in the fructification. Clinton (18, pl. 26) has already mentioned and illustrated similar differences in cultures of these organisms on agar in Petri dishes. In *Endothia parasitica* the pycnidia and spore masses are small, numerous, thickly scattered, and embedded in the mycelium. *E. fluens*, on the other hand, forms few, large, erumpent stromata, with spores extruding in thick, elongated masses. *E. tropicalis* closely resembles *E. parasitica* in number, size, and arrangement of pycnidia and spore masses, but differs in color of mycelium. *E. fluens mississippiensis* appears somewhat intermediate between *E. parasitica* and *E. fluens* in regard to the character and abundance of the pycnidia and in color of the growth. These peculiarities have been very uniform and constant in all the cultures on this medium and if they could be coordinated with regular morphological differences in nature would justify the separation of this form as a species. (See Pls. XIX and XX.)

CULTURES ON LIQUID MEDIA (IN 100 C. C. FLASKS).

Some difficulty was experienced at first in growing the species of *Endothia* satisfactorily on a liquid medium. Abundant growth was obtained on a medium suggested by Dr. Mel. T. Cook. This is a modification of the liquid medium No. II as given by him (19).

Cook's liquid medium, No. II, is prepared as follows:

Into 500 c. c. of distilled water put 15 grams of glucose and 20 grams of peptone steamed at 100° C. for three-fourths hour; into another 500 c. c. of distilled water put 0.25 gram of dipotassium phosphate and 0.25 gram of magnesium sulphate, steamed for 20 minutes; filter both 500 c. c. into same receptacle, steam 10 minutes, put into flasks, about 30 c. c. in each flask, and autoclave.

All species grew readily on this medium, *Endothia parasitica* even producing pycnospores. At the end of one month's growth the several species were readily distinguished on this medium and may be briefly described as follows:

Endothia gyrosa.—Growth scanty; did not form a continuous mat, but remained in small bunches, giving an almost flocculent appearance. The mycelium appeared white when removed from the culture solution, but the solution itself was honey yellow.

Endothia singularis.—Growth even less abundant than *E. gyrosa*; formed small brown knots against the glass. Mycelium buff, and the medium was changed to honey yellow.

Endothia fluens.—Growth somewhat more abundant and less closely matted than *E. parasitica*, entirely submerged; mycelium white; liquid unchanged in color.

Endothia fluens mississippiensis.—Growth slightly less abundant than in *E. parasitica*; submerged except at the very edges; much lighter in color, being reddish brown.

Endothia tropicalis.—This differed markedly from either *E. parasitica* or *E. fluens*. The mycelium formed a thin felt over the surface, white to salmon orange in color, with no change in the medium.

Endothia parasitica.—Mycelial growth very abundant, closely matted, chiefly submerged, but slightly arborescent in one or two small areas, which remained above the surface. Color, dark greenish brown.

CULTURES ON STERILIZED TWIGS (IN TUBES).

Early in this work it was noted that all the species of *Endothia* grew readily on sterilized chestnut twigs in test tubes. Later, tests were made with twigs from a number of common, woody plants. Twigs of *Acer saccharum*, *Alnus rugosa*, *Betula papyrifera* and *B. lenta*, *Carpinus caroliniana*, *Cornus florida*, *Fagus grandifolia*, *Fraxinus americana*, *Ostrya virginiana*, *Populus grandidentata*, *Prunus serotina*, *Rhus glabra*, *Tilia americana*, and *Tsuga canadensis* were collected in New York State early in June, placed in test tubes with a few cubic centimeters of distilled water and sterilized in an autoclave. All the species of *Endothia* were tested, and all grew on every species of twig except *Tsuga*. The difficulty of completely describing this series may readily be seen from the fact that each species of *Endothia* had a different appearance on every kind of wood.

In general it may be stated that *Endothia gyrosa* and *E. singularis* grew more slowly than the other species and produced no spores, while all the other species produced spores on most hosts. The mycelium of *E. parasitica* was usually white, especially on the bark. *E. gyrosa* and *E. singularis* produced various shades of buff, while *E. fluens*, *E. fluens mississippiensis*, and *E. tropicalis* developed a much more brightly colored mycelium, usually showing yellow or orange shades.

MOISTURE RELATIONS.

In an earlier paper (77, p. 7) the writers reported tests with *Endothia fluens* and *E. parasitica* on media containing various percentages of water. It was observed that pycnospore production began earliest and was most abundant on the media containing the least moisture.

Aside from this the writers have thus far been unable to make definite tests as to the moisture relations of these fungi. However, incidental observations in connection with the light tests (p. 43) and temperature tests (p. 45), as well as results of field experiments, particularly those at Woodstock, N. Y., make it apparent that the amount of available moisture is a very important factor in the fructification of the fungus.

LIGHT RELATIONS.

The relation of light to pycnospore production in *Endothia parasitica* was first discussed by Anderson (1, p. 20). He says—

When plate cultures are grown in total darkness on chestnut-bark agar, no pycnidia are developed, while on plates made at the same time and grown in the light, the usual rings of pycnidia appear (fig. 57). Experiments were also tried in which the plate was left in darkness until about half covered with mycelium and then brought into the light. Circles of pycnidia were developed, beginning with the ring which marked the outermost limit of the colony when removed from the dark chamber. The concentric rings which always appear on agar cultures are due to the alternation of night and day.

Later, in a bulletin by Anderson and Rankin (6, p. 592), the same results are attributed to D. C. Babcock.

Up to the time the above-mentioned work was published the writers had grown about 3,000 cultures of the several species of *Endothia* on various media in flasks and tubes. Practically all of these cultures had been kept in dark cases and *Endothia parasitica* had produced pycnidia abundantly on most of the media used. It seemed desirable, therefore, to determine whether wholly different light relations existed when the fungus was grown on plates. The following series of tests was accordingly made, using *E. parasitica* only.

LIGHT TESTS OF CULTURES ON PLATES.

In experimenting with plate cultures in order to check up the results reported by Anderson and Rankin (6, p. 592) it was noted that there was great variation in the rate at which the cultures dried out. There was considerable variation in this respect in different plates kept side by side, apparently due to differences in the Petri dishes, and a marked difference between cultures kept in light and those kept in darkness. Since a causal relation between lack of moisture and abundant spore production had already been shown, it seemed probable that this might influence the results of the light tests in plate cultures. In fact, in a few cases the cultures kept in the light did produce spores earlier than those kept in darkness. Accordingly, in order to eliminate at least in part this fact which seemed to obscure the possible effect of light, a method was sought of equalizing the loss of moisture. In the following series half the plates were placed under a plain bell jar and the other half under a bell jar of equal size but darkened by being covered inside and out with heavy black paper, such as is used to wrap photographic plates. The two bell jars were then set side by side in front of a north window. By this means the conditions were made much more uniform as to temperature and moisture. There was still a slight difference in the rate of drying and undoubtedly at times a difference

in the temperature of the light and dark plates, but probably not sufficient to interfere seriously with the experiments.

Series 1. On corn-meal agar plates under bell jars.—In nine days there was no distinguishable difference between the plates in light and darkness, a few spore masses occurring near the middle of each.

In 18 days most of the light plates showed a central ring of spore masses and a zone of scattered spore masses near the edge. The dark plates showed a few small spore masses near the center, and scattered about the outer portion were the small masses of mycelium which usually constitute the early stages of pycnidial formation.

In 30 days the number of spore masses had increased somewhat in both sets of plates, but more in the darkened plates, so that the number of spore masses was about equal in all the plates. The two sets of plates were fairly uniform as to the arrangement of the spore masses. Plate XVIII shows a typical example.

Series 2. On chestnut-twigg agar plates under bell jars.—After nine days the cultures in light and darkness were alike. No spores had yet appeared in either set.

In 30 days there were a few spore masses on nearly all of the plates, there being no difference between those in light and those in darkness either in number or distribution.

Series 3. On corn-meal agar and chestnut-twigg agar under bell jars.—In this test the plates were piled alternately, first a corn-meal and then a chestnut-twigg agar plate, so that the two media would be under conditions as nearly identical as possible. The plates were inoculated as before and left untouched for 18 days and after that were examined daily. After 18 days all the corn-meal plates showed spore masses in practically equal numbers, while the chestnut-twigg agar plates showed no spore masses whatever. There was no apparent difference in the growth on either medium between the plates in light and those in darkness.

At the end of 25 days the cultures on chestnut-twigg agar plates showed numerous small masses of mycelium, indicating the formation of pycnidia. No difference was perceptible between the dark and light plates.

In 28 days, from 100 to 150 of these pycnidia in each plate were extruding spore masses. The light plates showed in general a larger mass of spores than the dark plates, but this was not marked, certainly no greater than was accounted for by the unavoidable difference in radiation and the consequent difference in moisture. This difference in the moisture of the medium was clearly shown each morning by the greater amount of moisture condensed on the covers of the darkened Petri dishes.

At this time (after 28 days) four corn-meal agar plates which had been wrapped in four layers of heavy black photographic paper and

placed on a window sill were opened and examined. In spite of the cold weather prevailing during this test and the consequent low temperature of the room at night, these plates contained an average of nearly 200 well-developed spore masses.

At the end of 35 days the chestnut-twigg agar plates which had been kept in the light showed an average of 160 spore masses, while those kept in darkness showed an average of 130 spore pustules, a comparatively small difference in favor of the light plates. There was, however, a wide difference between the various plates in each series, and it was impossible in most cases to distinguish cultures grown in the light from those grown in darkness either by the number, size, or arrangement of the pycnidia and spore masses.

From these experiments it is evident that pycnidia are produced abundantly in total darkness on chestnut-twigg agar as well as on other favorable media. There is no perceptible difference in the amount of spore production or in the arrangement of pycnidia between cultures kept in total darkness and those kept in the light during the day if the temperature and evaporation remain the same in both. Continued observation of numerous cultures grown both in daylight and in darkness has convinced the writers that light has no perceptible effect on mycelial growth either in amount, nature, or color production. It seems evident, therefore, that light is a negligible factor in the growth and fructification of these fungi.

TEMPERATURE RELATIONS.

In an earlier paper (77, p. 9) the writers published the results of three series of tests made to determine the temperature relations of three species of *Endothia*. Since the publication of that paper cultures of other species and additional material of some of the species from widely separated localities have been secured. Four series of temperature tests including this new material were made on solid media.

TESTS ON SOLID MEDIA.

In these tests cultures of *Endothia gyrosa*, *E. singularis*, *E. fluens*, *E. fluens mississippiensis*, and *E. parasitica* were tried on corn-meal agar in slanted tubes, oatmeal in flasks, and potato agar in slanted tubes. The cultures tested were from specimens chosen from the extremes of the known ranges of the fungi and from their different hosts. No difference could be detected in the various cultures of the same species, even in those from widely separated localities and from different hosts. Cultures appeared to have the same temperature relations whether made from spores or mycelium. The results may be briefly summarized as follows:

At 41° and 39° C. there was no growth in any species. Cultures removed from the incubator at the end of 11 days and kept at room temperature showed no growth.

At 35° C., *Endothia gyrosa*, *E. singularis*, and *E. parasitica* showed a slight development within 2 days, but at the end of 11 days it was still slight and abnormal in appearance. *E. fluens* and *E. fluens mississippiensis* showed no growth at this temperature.

At 31° C., *Endothia gyrosa*, *E. singularis*, and *E. parasitica* appeared about the same as at room temperature for the first four days. At the end of six days these species showed somewhat less growth than at room temperature, while at the end of two weeks the growth was less in extent and markedly less freshly colored than that at room temperature. *E. fluens* and *E. fluens mississippiensis* showed somewhat less growth than at room temperature even in 4 days, and markedly less at the end of 2 weeks.

At room temperature (which at this time varied from 20° to 24° C.) the growth was much as described in the previous paper. Within 11 days growth was practically complete and in 14 days there was abundant spore production in *Endothia parasitica*.

At 18° and 16° C., all species showed considerably less growth than at room temperature, but there seems to be little difference in the comparative growth of the various species at these temperatures. At 13° the growth was decidedly less than at 16° C. but was fairly normal in appearance in all the species except that *Endothia fluens mississippiensis* failed to produce the characteristic color at this temperature.

At 9° C. there was a very slight growth in all species.

At 7°, 5°, and 2° C. there was no growth whatever. Cultures removed to room temperature at the end of 11 days developed normally and at about the same rate as in newly made cultures.

These additional tests seemed to confirm the results already published (77, p. 27); that is, growth was best in all species at ordinary room temperature, about 20° to 24° C. The minimum temperature for all was about 9°, and all failed to grow at 7° C. The maximum temperature for *Endothia gyrosa*, *E. singularis*, and *E. parasitica* appeared to be about 35°, while the maximum for *E. fluens* and its variety *E. fluens mississippiensis* was apparently about 32° C. At all the temperatures tried *E. singularis* grew much more slowly than any of the other species.

It was noted that cultures kept at 7°, 5°, and 2° C. showed no growth, but when removed to room temperature developed normally, while cultures kept at 41° and 39° C. failed to grow when removed to room temperature. This seemed to indicate that the fungi are more susceptible to heat than to cold, and such is perhaps the case. There was, however, the additional factor of moisture involved, for while the agar of the cultures kept at 7° and lower was in apparently the same condition at the end of 11 days as when first inoculated, the agar of the cultures kept at 41° to 39° C. was considerably dried. This raised the question as to whether the drying out of the agar had not affected the growth of the fungi in those cultures kept above room temperature as much as the higher temperatures themselves.

The same idea was suggested by the fact that several of the species grew for a few days at 31° C. as well as they did at room temperature, and then fell behind. It seemed possible that this falling off in the

rate of growth might be due, at least partly, to more rapid drying of the agar at 31° C., or possibly to the more rapid development of some toxin, as was suggested by Balls (7) to explain a similar observation on the "soreshin" fungus. These observations threw doubt upon the accuracy of the writers' previous conclusions, and made it seem possible that the optimum temperature of the species of *Endothia* might be well above room temperature. This could only be determined accurately by some method which would control temperature without altering the supply of moisture. Some months after the above tests were concluded it was discovered that the various species of *Endothia* would grow readily on several liquid media. Consequently, several series of tests on liquid media were run parallel to those described above, except that the tests were continued for only four days. Experiment showed that at the higher temperatures the medium became considerably reduced by evaporation if left for a longer period.

TESTS ON LIQUID MEDIA.

In the series of tests on liquid media, all the species of which cultures had been obtained were grown on Cook's medium (see p. 41) both in tubes and in flasks, using ten tubes and six flasks at each temperature. The cultures of *Endothia gyrosa* and *E. singularis* were made with bits of mycelium from pure cultures. The other species were grown from conidia and the cultures were kept for two days at room temperature, in order to allow the conidia to germinate before being placed in the temperatures to be tested.

The following temperatures were used for making the tests: 40°, 37.5°, 35°, 29°, and 27°, and room temperature which was fairly constant at about 22°, 17°, 12°, 9°, 7°, 3°, and 2° C. There was some variation in the temperature of the incubators and refrigerators used, but in most cases they did not vary more than 1 degree above or below the temperature indicated. At 40° there were occasional traces of growth, especially in *Endothia parasitica*, but this may have occurred when the incubator dropped to 39° C. There is no regular and continued growth at this temperature.

At 37.5° C. there was perceptible growth in all the species. This is in striking contrast to the results on solid media, as no species grew at a temperature above 35° C. on solid media.

At 35° C. *Endothia parasitica* showed practically the same amount of growth as at 27° and 29° C. for the first three days, but fell behind after that. *E. fluens* showed less growth at 35° than at the lower temperatures. These two species were the only ones tested at 35° C.

At 27° and 29° C. growth was markedly more abundant than at 37.5°, and in most of the species was more abundant than at room temperature. In *Endothia gyrosa* and *E. fluens mississippiensis* the

growth at 27° C. was apparently equal to that at room temperature. At 22° C. (room temperature) all species developed much more rapidly than at the lower temperatures. At 17°, 12°, and 9° C. there was progressively less and less growth. At 7° C. and lower there was no growth whatever.

While these tests are not wholly satisfactory and must be regarded only as approximations, they are of some interest. Below 7° C. there is no growth in any species.

It is evident that there is a considerable range of temperature, from below 20° to well above 30° C., within which the species of *Endothia* grow readily. Within this range there may be a definite optimum for each species, but this has not yet been determined. For *Endothia parasitica* the optimum appears to be at 27° C. or above, and the same may be true of the other species.

At 40° C. or above no growth occurs. There is considerable evidence, however, that *Endothia fluens* is less resistant to the higher temperatures than either *E. parasitica* or *E. gyrosa*. After several of the tests the flasks were kept at room temperature for some days. It was found that all developed normally except those which had been kept at 40° and 37.5° C. These developed more slowly than those which had been kept at lower temperatures. It was particularly noticeable also that *E. parasitica* and *E. gyrosa* developed practically as well after being kept at 40° as at 37.5° C., while cultures of *E. fluens* which had been in 37.5° developed fairly well; but if kept at 40° for three days they entirely failed to develop.

DISTRIBUTION OF THE SPECIES OF ENDOTHIA.

During the past two years the writers have studied over 600 specimens of *Endothia* from various parts of the world. The greater number of these specimens have naturally come from the United States. The maps (figs. 1-4) show the known ranges of the various species in this country. Each dot on a map represents a locality from which the species has been collected. Frequently, of course, many specimens have come from a single locality; hence the number of dots by no means represents the number of collections.

In the case of *Endothia parasitica*, the dark portion represents the area over which the blight is practically continuous; that is, practically all the stands of chestnut are either diseased or dead. The dots represent known isolated infections and the solid line marks the botanical limit of the chestnut.

Endothia gyrosa is known only from the United States, but has a range in this country wider than that of any other species. As shown in figure 1, it has been found as far north as central Michigan, east to Connecticut, on the Pacific coast near San Francisco, and on

the Gulf of Mexico. There is, however, a very great difference in the abundance of this species at different points. In the southeastern United States—that is, the region south of central Indiana and southern Virginia and east of central Arkansas and Louisiana—this species occurs in great abundance wherever its hosts are found. Broken branch stubs and exposed roots of *Liquidambar*, *Fagus*, and *Quercus* are covered with fructifications of this fungus. This is especially true of roots exposed by erosion or excavation which have suffered mechanical injury through the tramping of men or cattle. Farther north in Maryland, New Jersey, and Connecticut only an occasional specimen is found. Three days' search in southern Con-

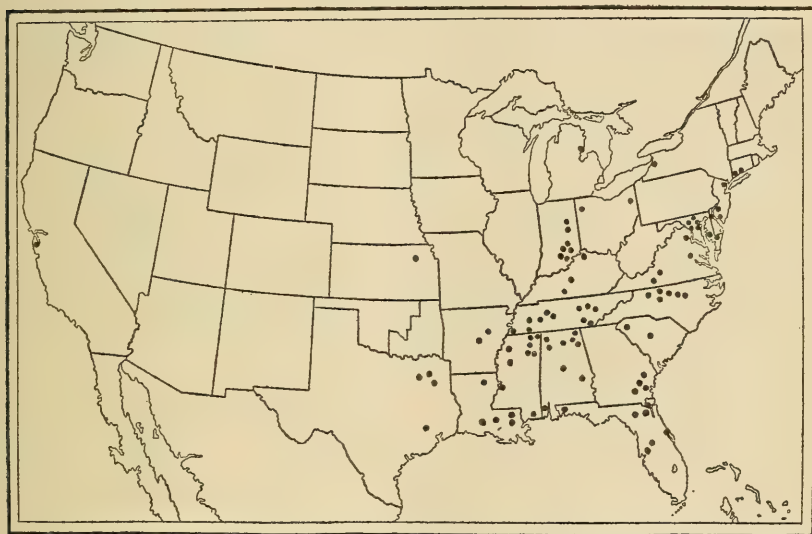


FIG. 1.—Outline map of the United States, showing the distribution of *Endothia gyrosa*.

necticut, for example, yielded only two specimens, both on *Liquidambar*, showing pycnidia only.

Endothia singularis is known at present only on oaks in the dry foothill regions of Colorado and New Mexico. Bethel, in a letter, states that it is very abundant in certain localities in Colorado.

Endothia fluens has long been known to occur in both Europe and America. Recently, through the kindness of Dr. Y. Kozai, director of the Central Agricultural Experiment Station, Nishigahara, Tokio, Japan, the writers received four specimens of fungi on chestnut. One of these, collected by S. Tsuruta on October 14, 1914, in the Province of Totomi, was the pycnidial stage of an *Endothia*, which when cultured proved to be *E. fluens*. Ascospore material of this species has since been collected by Meyer at Nikko, Japan, on the bark of *Pasania* sp.

Endothia fluens, while common to Europe, Asia, and America, has a much more limited range in the United States than *E. gyrosa*. It is fairly common on *Castanea* and *Quercus* from southern Pennsylvania and Ohio to northern Mississippi and Alabama. In southeastern Pennsylvania it has been found so far only on roots of *Quercus*, and in northern Mississippi and Alabama only on *Castanea dentata*.

Endothia fluens mississippiensis was first sent to the writers from Corinth, Miss., by Mr. T. E. Snyder, of the Bureau of Entomology, and has since been collected in only four other localities, three near the northeastern corner of Mississippi and one in central Kentucky.

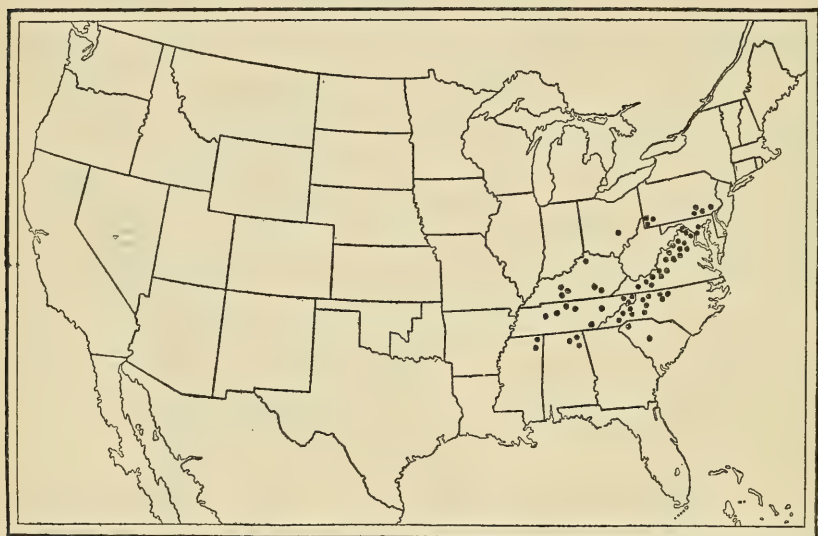


FIG. 2.—Outline map of the United States, showing the distribution of *Endothia fluens*.

As both *Endothia gyrosa* and *E. fluens* were collected in this country nearly a century ago by Schweinitz, it seems altogether probable that they are indigenous species which may have already reached the limits of their natural ranges in this country.

While the maps (figs. 1-4) do not give by any means every locality where *Endothia* is to be found and specimens are likely to be collected at many points outside the present known range, the writers feel justified in assuming that these maps represent the limits of the territory where *Endothia gyrosa* and *E. fluens* may commonly be found. This is especially true in the eastern portion, where the field has been rather thoroughly worked. It is unlikely, for instance, that *E. fluens* occurs abundantly in southern Alabama and Georgia, where *E. gyrosa* was found so commonly. Southeastern Pennsylvania must be somewhere near the northern limit for *E. fluens*, for the writers' four collections in that region are the result of six days'

search. At the northeastern limit of *E. gyrosa*, Clinton (15, p. 79) found only a single specimen after two years' search, and the writers have looked for it in all the other New England States without finding a single specimen. The report of *E. gyrosa* from Massachusetts by Hitchcock (42, p. 63) has already been shown to be a probable error in identification.

FACTORS INFLUENCING DISTRIBUTION.

HOST RELATIONS.

Just what determines the present ranges of the species can not, of course, be positively decided, but some relation to certain external factors may be traced. Neither species has the same distribution as



FIG. 3.—Outline map of the United States, showing the distribution of *Endothia fluens mississippiensis* and *E. singularis*. The dots indicate collections of *E. fluens mississippiensis* and crosses indicate collections of *E. singularis*.

its hosts. *Quercus* and *Fagus* are both abundant farther north than *Endothia gyrosa* has yet been found, while *Quercus* is abundant north and south of the known range of *E. fluens*. It may be worthy of note, however, that *E. gyrosa* extends north as far as *Liquidambar* is found. Perhaps more significant is the relation of the range of *E. fluens* to that of the chestnut. As will be seen from a comparison of the maps (figs. 2-4), *E. fluens* is not found abundantly at any point outside the natural range of the chestnut. Especially interesting is the fact that the southeastern limits of *E. fluens* and *Castanea dentata* are practically coincident, for in this region *Endothia fluens* was found only on *Castanea*, never on *Quercus*. This suggests the possibility that *Castanea* may be the original and favorite host of *Endothia fluens*.

SOIL CONDITIONS.

Greater opportunity for infection seems to be an important factor in the greater abundance of *Endothia* in the South. By far the most favorable places of infection, especially for *Endothia gyrosa*, are bruised or broken but still living roots. Soil, cultural, and climatic conditions combine to make these many times more abundant in the Southern States than elsewhere. The more sandy and easily eroded soil, usually without turf, subject throughout the winter to the action of wind and rain, leaves innumerable oak roots exposed, which are readily injured by vehicles and the tramping of horses and cattle, leaving wounds suitable for the entrance of *Endothia*. In the

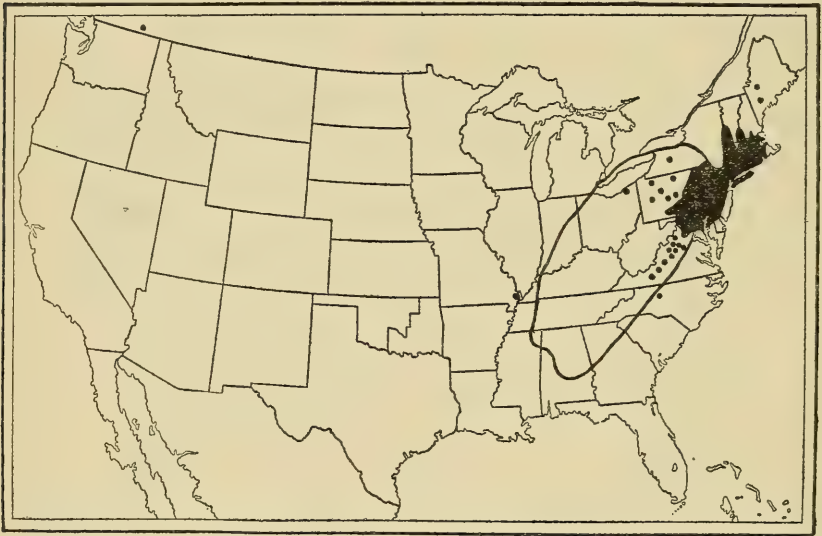


FIG. 4.—Map of the United States, showing the distribution of *Endothia parasitica* in December, 1915. The solid portion shows the area in which *E. parasitica* is generally present. The dots indicate scattered infections. The heavy line shows the limits of the range of *Castanea dentata*.

North, the more rocky soil, frequently covered with sod, protected through much of the winter by snow, makes exposed roots much less common, and the roots so exposed are rather less subject to mechanical injury. In the writer's experience the most favorable localities for collecting *E. gyrosa* are the unfenced public squares of Southern towns, where partial grading, erosion, and constant traffic have left hundreds of oak roots exposed, and the pastures of southwestern Indiana, where the roots of *Fagus* are often found injured by cattle.

COMPETITION AMONG FUNGI.

The writers' extensive field studies and observations have convinced them that competition among fungi must be considered as a

factor in determining their distribution. As already stated, while *Endothia fluens* occurs on *Quercus*, it has been found toward the southwestern limit of its range (northern Mississippi and Alabama) only on *Castanea*, and in Tennessee the writers have sixteen collections of this species on *Castanea* and only three on *Quercus*. In this same region, *E. gyrosa* is everywhere abundant on *Quercus*. In numerous inoculations with *E. gyrosa* and *E. fluens* on oak it has been found that *E. gyrosa* is more generally successful than *E. fluens*. Moreover, *E. gyrosa* occurs abundantly on *Liquidambar* and *Fagus* in this region, thus providing more numerous sources of infection for this species than for *E. fluens*. It seems highly probable, therefore, that *E. gyrosa*, with its greater affinity for oak and greater opportunity for infection, may occupy the available oak roots to the exclusion of *E. fluens*, even though climatic conditions are favorable for the growth of the latter species. *Castanea* rarely serves as a host for *E. gyrosa*; consequently, on this host *E. fluens* meets with little competition and is very abundant.

In the northeastern limit of its range, *Endothia fluens* has been found only on oak roots. Whether it grows naturally on chestnut in this region can not well be determined, since practically all the chestnut trees here are dead or badly diseased with *E. parasitica*. *E. gyrosa* is rare in this region, but *E. fluens* here evidently comes into competition with *Valsa frustum-coni* (Schw.) Curtis, which is common on exposed roots of various species of *Quercus*.

CLIMATE.

Since none of the species of *Endothia* in America extends to the limits of its host species, climate probably has an important part in determining their present ranges.

In this connection it is of interest to compare several life zone and climatic maps which have been published with the range maps of the various species of *Endothia*. The map entitled "Life zones of the United States," by C. Hart Merriam (50, pl. 14), is based largely on a study of animal life. Merriam deduces from his studies the conclusion that the northward distribution of animals and plants is determined by the total quantity of heat and their southern distribution by the mean temperature of the hottest part of the year. The life zones which he outlines show, however, a striking relation with the known ranges of *Endothia* in America. With the exception of a single locality for *Endothia gyrosa* in Michigan, all the known localities for *E. gyrosa* and *E. fluens* fall within the Upper Austral and Lower Austral zones. All the known localities for *E. fluens* and all the region where *E. gyrosa* has been found abundantly fall within the humid divisions of these zones. The northeastern limits of the Upper Austral coincide very closely with those of *E. gyrosa*; its

limits in Pennsylvania include the northern localities known for *E. fluens*, while the southern limits of this zone coincide closely with the southern limit of *E. fluens*.

The Livingstons (47) have published maps based on temperature summations and temperature efficiencies, as well as maps in which isoclimatic lines of temperature are combined with precipitation indices and evaporation indices for the mean frostless season.

While no very definite relations between these maps and the ranges of *Endothia* can be traced it is noteworthy that the localities where *Endothia gyrosa* is known to be abundant are all south of or near the 600 line of temperature efficiency, and only one collection of *E. gyrosa* has been made north of the 400 line. *E. singularis*, on the other hand, has thus far been found only north of the 400 line.

Zon's map (86) of vegetal regions of the United States is based on periods of growth and rest. The regions where *Endothia gyrosa* and *E. fluens* are abundant are all south of the line which marks the northern limit of seven months' vegetation. In fact this coincides very closely with the northern limit of *E. fluens*, and no specimen of *E. gyrosa* showing ascospores has been found farther north.

The relations pointed out above strongly suggest the possibility of some causal connection between climatic conditions and the present ranges of *Endothia* species, but just what factors may limit the spread of the species is not yet determined. The temperature tests recorded on pages 45 to 48 throw little light on this problem, for the maximum and minimum temperatures are about the same in the various species. *Endothia fluens* seems to be less resistant to the effects of high temperature (40° C.), but it is difficult to see that this fact alone has any direct bearing on the question of distribution.

DISCOVERY OF ENDOTHIA PARASITICA IN CHINA.

For eight years after its discovery in the New York Zoological Park in the summer of 1904, *Endothia parasitica* was known only from eastern North America. During this time two quite different opinions as to the origin of the fungus were advanced. Some investigators maintained that *E. parasitica* was an indigenous fungus (15); others that it had been imported from some foreign country, probably oriental (51, 52.) In the fall of 1912, however, pycnospore material was sent from Agassiz, B. C., by H. F. Güssow, Dominion Botanist of Canada. Cultures made from this material were identical with *E. parasitica*, and a series of inoculations on *Castanea dentata* produced typical cankers. Later, a large quantity of material collected at Agassiz by Dr. James R. Weir was received, which included a few ascospores. These proved to be typical *E. parasitica*.

A brief description of the identification of other specimens of *E. parasitica* from Agassiz is given by Faull and Graham (29). These writers report that in the material sent them in the summer of 1913 there were no perithecia, but that the pycospores were typical *E. parasitica* and the characteristic mycelial fans were present in the bark. Cultures of the fungus proved it to be identical with *E. parasitica*. They also state (p. 203) that the chestnuts grown at Agassiz "are of oriental, European, and American origin. The stock was purchased from nursery firms located in New Jersey, Ohio, and California. One of these at least 'was a heavy importer of oriental trees and shrubs'." They suggest that it "is significant that a connection with the Orient exists."

In support of this view, the statement of Mr. Sharpe, who had charge of planting the nut orchard at Agassiz, may be given. Dr. Weir visited Mr. Sharpe at Salmon Arm, B. C., and Mr. Sharpe stated definitely to him that he would be willing to furnish affidavit to the effect that in the main or entirely the chestnut trees in the nut orchard were originally imported from the Orient; in fact, a part of the trees, according to Mr. Sharpe, undoubtedly came from Japan or China and were shipped to Agassiz in the original wrappings, which consisted of the peculiar mats and casings of those countries.

In a letter accompanying the specimens from British Columbia Güssow states that "these trees may be regarded as absolutely isolated. There is no other chestnut tree anywhere round it for 500 miles and more." It seems highly probable therefore that *E. parasitica* was carried to this locality on nursery stock, perhaps as suggested by Faull and Graham and by Weir by importation from the Orient.

The following spring (1913) Mr. Frank N. Meyer, agricultural explorer, discovered this fungus in Chihli Province, China, under such conditions as could leave no doubt that it is indigenous there. The account of this discovery and its corroboration in this country was published by Fairchild (27), and also by the writers (76).

As outlined by Fairchild (27), Meyer first found the diseased chestnuts near Santunying, a small town $1\frac{1}{2}$ days journey by cart from a railroad, northeast of Peking in Chihli Province, between Tsunhua-tcho and Yehol.

A small specimen of diseased chestnut bark from this region was inclosed in a letter from Mr. Meyer which was received by Mr. Fairchild on June 28, 1913. From this specimen, which showed only pycnospores, cultures were obtained, which proved it to be true *E. parasitica*. On July 23 more Chinese specimens were received from the same locality, as well as from Scha Ho in the same Province. These included a large canker on a chestnut branch about 6 cm. in

diameter, which agreed in every respect with cankers produced on varieties of Japanese chestnuts in this country (Pl. XXII).

Other specimens in this collection showed well-developed perithecia and ascospores. The ascospore measurements made at the time, as well as the cultures of the Chinese fungus and the inoculation experiments on *C. dentata*, are described in the previous paper by the writers (76, p. 296).

Shortly after this first series of inoculations was made subcultures of the Chinese material were sent to several investigators who had been studying the chestnut-bark disease, in order that the *Endothia* from China might be tested as soon as possible under American conditions by inoculations at various points throughout the known range of the disease.

A series of inoculations was made by Prof. J. Franklin Collins at Martic Forge, Pa., on July 14, 1913, using American and grafted Paragon and grafted Japanese chestnut trees. Another series of inoculations, 56 in number, was made at the same locality September 10, 1913, by Dr. Caroline Rumbold on grafted Paragon chestnuts. Twenty inoculations were made on native chestnuts at Anderson, Pa., October 2, 1913, by Dr. F. D. Heald and R. A. Studhalter. Inoculations with the Chinese *Endothia* were made at Leesburg, Va., on both *Castanea dentata* and *C. pumila* by G. Flippo Gravatt and J. T. Rogers, August 16, 1913.

All these investigators made duplicate inoculations with American material, and all agreed that the Chinese fungus was identical in its effects on the host with the American chestnut-blight fungus. During the season of 1914 numerous inoculations with material from China were made by the writers at various points in New Hampshire, Massachusetts, Connecticut, New York, Delaware, and Maryland, while others have been made in Rhode Island by Prof. Collins with the same results.

ADDITIONAL CHINESE SPECIMENS.

Since the publication of the previous paper (76) additional specimens of *E. parasitica* from China have been received from Meyer; one collected at Changli, Chihli Province, China, October 13, 1913, by Mrs. Mary S. Clemens; a quantity of material collected by Meyer himself in the village of Tachingko, near Taianfu, Shantung, China, March 21, 1914; and another collected by him at Yatyeko, Shensi, China, September 2, 1914. A few cankers have also been sent by Meyer, collected by him at Shihbonshan, near Hangchow, Chekiang Province, China, June 26, 1915. The label on this specimen bears the further comment, "very destructive in this locality." Cultures have been made from all these specimens and have invariably proved to be identical with cultures of *E. parasitica* found in this country.



AN OLD CANKER CAUSED BY *ENDOTHIA PARASITICA* ON A BRANCH OF *CASTANEA MOLLISSIMA*.

Collected by Frank N. Meyer, May 31, 1913, near Santunying, Chihli Province, China.

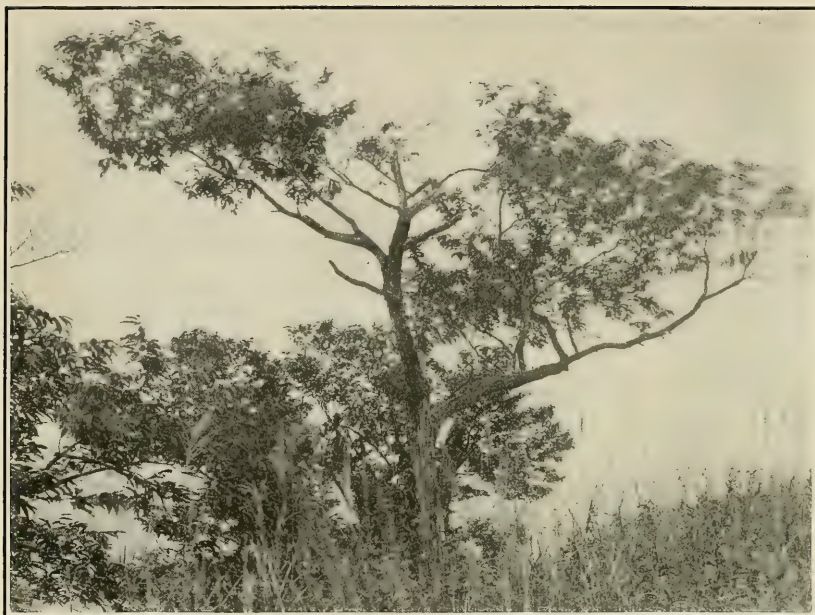


FIG. 1.—JAPANESE CHESTNUT AT NIKKO, JAPAN, FROM WHICH THE CHESTNUT BLIGHT FUNGUS (*ENDOTHIA PARASITICA*) WAS COLLECTED BY F. N. MEYER, ON SEPTEMBER 17, 1915.



FIG. 2.—TWO BRANCHES OF A JAPANESE CHESTNUT. THE LARGER (TO THE LEFT) WAS BROUGHT TO THIS COUNTRY BY F. N. MEYER, AND FROM IT *ENDOTHIA PARASITICA* WAS ISOLATED.

As Tachingko is 300 miles south of Changli, where *E. parasitica* was first collected by Meyer, and Yatyeko is 500 miles west of Tachingko, it seems highly probable from the collections that *E. parasitica* is widely distributed in China (fig. 5).

Meyer, writing from Hangchow, July 1, 1915, refers as follows to the condition of the chestnuts in that locality:

Well, I have a few interesting discoveries to report. First, there are many specimens of *Castanea mollissima* scattered at the bases and on the lower slopes of the hills around here, and these chestnuts are seriously attacked by the bark fungus, and in my estimation are going to succumb to it these coming years. The chinquapins (*Castanea* spp.), however, which are very abundant on the higher and more sterile hill slopes, seem to be immune;



FIG. 5.—Outline map of China and Japan, showing the localities in which *Endothia parasitica* has been found.

at least I did not see any evidences of damage or even of attacks. This brings another interesting point to my mind. I was told in Nanking that various missionaries at Kuling, the great summer resort in central China for missionaries, were cutting down their chestnuts, as the tops were all dying, due to borers working underneath the bark.

Meyer has since stated to the writers that he believes the destruction of the chestnut at Kuling is due to *Endothia parasitica* rather than to borers.

In the writers' earlier publication the following statement was made (76, p. 297):

The Chinese organism has thus been shown to be practically identical with the American in all its morphological and physiological characters and in the production of the typical chestnut blight and the pycnidial fructifications

of the fungus. There is apparently but one other requirement that could be made according to the strictest pathological canons to perfect the proof in this case, and that is the production of typical ascospores of *E. parasitica* on the lesions produced by the inoculations.

The last requirement has now been fulfilled. Specimens collected February 15, 1915, from inoculations made September 20, 1913, on chestnuts in Virginia, near Point of Rocks, Md., with Chinese material, show perithecial stromata with typical ascospores of *E. parasitica*, thus completing the evidence.

DISCOVERY OF ENDOTHIA PARASITICA IN JAPAN.

More than two years after his original discovery of *Endothia parasitica* in China (June 3, 1913), Meyer also discovered the fungus in Japan. A brief account of his discovery has already been published by the writers (78). It may be sufficient here to state that following the discovery of *Endothia parasitica* in China the writers endeavored by correspondence to obtain the fungus from Japan. While not successful in obtaining *Endothia parasitica*, the writers did receive several specimens of fungi, including species of *Endothia* on species of *Castanea*. These, together with several specimens of fungi found on chestnut nursery stock from Japan, make it clear that there are in that country several *Pyrenomyces* other than *Endothia parasitica* more or less parasitic on *Castanea*.

Meyer first discovered the chestnut-blight fungus in Japan at Nikko, September 17, 1915, on wild trees of *Castanea crenata* Sieb. and Zucc. A photograph of the trees from which he collected specimens of *Endothia parasitica* is shown in Plate XXIII, figure 1, and a branch from which the diseased material brought to the United States was taken is shown in Plate XXIII, figure 2.

Shortly after Meyer's arrival in Washington in December, 1915, the specimens collected at Nikko were turned over to the writers for study. Examination at once showed cankers and mycelial fans typical of *Endothia parasitica*. The material also contained typical pycnosporangia and ascospores of the fungus. Cultures made from single ascospores on various culture media proved to be identical with those of *Endothia parasitica* found in this country and in China, thus establishing beyond question the identity of the fungus.

Meyer's observations as to the resistance of the Japanese chestnuts to this disease are of great interest. He states that the trees vary considerably as regards their power of resistance, but that in general the Japanese chestnut is even more resistant to *Endothia parasitica* than is the Chinese chestnut (*Castanea mollissima*).

As announced in the same publication (78), *Endothia parasitica* was collected by Dr. Gentaro Yamada at Morioka, northern Japan. These specimens, which show typical cankers as well as ascospores of the fungus, were received by the writers on January 8, 1916.

PRESENT DISTRIBUTION OF ENDOTHIA PARASITICA IN AMERICA.

The present range of *Endothia parasitica* in America, as shown by the map (fig. 4), is probably merely the extent to which it has been able to spread in the time since it was first introduced.

Whether *Endothia parasitica* was introduced into one locality or several is uncertain, but the studies of Heald (40, 41) and others have shown clearly that the spores of *E. parasitica* are carried by the wind, by insects and birds, and on nursery stock, which would account for its wide distribution and for its occurrence in isolated localities, long distances away from the main body of the disease. It also makes it seem probable that the fungus will continue to spread with some rapidity.

Certainly, there is no evidence that any factor, climatic or otherwise, is likely to prevent the spread of this fungus into the large area of chestnut south of its present range. On the contrary, the duplicate inoculations made by the writers show clearly that the fungus grows more rapidly at the southern limit of its present range than farther north, where it is much more common. The longer growing season in the South is also no doubt an important factor.

In this connection, it may be noted that Köppen (46), in his map of the vegetation regions of the earth, places the portion of China where *Endothia parasitica* has been found indigenous in the same climatic region as that portion of the United States where it is now doing such destructive work. He designates this region as the "Hickory" division of the mesotherms.

HOST RELATIONS OF THE SPECIES OF ENDOTHIA.

ENDOTHIA GYROSA.

Endothia gyrosa occurs commonly on Liquidambar, Fagus, and Quercus, occasionally on Castanea, and has been found on Vitis in Alabama, but the writers were unable to obtain fresh material from this host.

While Fagus and Quercus are, of course, closely related, it seems remarkable that a fungus should be abundant on hosts so different as Liquidambar and Quercus, yet so rare on any other host as to be only once reported. It seemed possible, indeed, that the fungus on Liquidambar, while morphologically and culturally identical with that on the various other hosts, might prove to be physiologically different. In order to obtain more definite information on this point, several series of cross inoculations were made.

It had been observed that *Endothia gyrosa* was found most frequently on the cut or broken ends of branches or on exposed, bruised, or broken roots. In making inoculations, therefore, a small branch,

1 inch or less in diameter, was cut off about 6 inches from the main trunk. Mycelium from corn meal in flasks was placed on the cut end of the stub and covered with wet cotton, over which oiled paper was tied. In about two weeks the paper and cotton were removed. In all cases, branches similar to those inoculated were cut as checks.

TABLE III.—*Inoculations with Endothia gyrosa.*

Source of fungus and date.	Host inoculated.	Number of inoculations.	Number successful.	Remarks.
Fagus:				
May 8, 1913.....	Castanea.....	6	3	Pycnospores first observed on Oct. 16.
May 29, 1913.....	Fagus.....	3	3	Pycnospores first observed on Aug. 29 for two and on Oct. 10 for the third.
Sept. 15, 1913.....	Liquidambar.....	5	2	No growth until the spring of 1914; pycnidia scattered and small on Oct. 13.
Do.....	Quercus.....	4	2	No growth until spring; well developed on Oct. 13, 1914.
Apr. 2, 1914.....	Fagus.....	4	0	
Do.....	Quercus.....	4	0	
Do.....	Castanea.....	4	2	Pycnidial stromata well developed on Oct. 13, 1914.
May 23, 1914.....	do.....	4	4	Do.
Do.....	Liquidambar.....	4	0	
Do.....	Quercus ¹	4	0	
Do.....	Fagus.....	4	3	Do.
Quercus:				
May 29, 1913.....	do.....	3	3	Pycnospores first observed on Aug. 29, 1913.
Do.....	Liquidambar.....	4	2	Very slight indications of growth on Aug. 29, 1913; a few pycnidia with spores on Oct. 16.
Sept. 15, 1913.....	do.....	8	0	
Do.....	Castanea.....	4	2	Large well-developed pycnidia on Oct. 13, 1914.
Apr. 2, 1914.....	Fagus.....	4	0	
Do.....	Quercus ¹	4	0	
Do.....	Castanea.....	4	4	Large abundant pycnidial stromata on Oct. 13, 1914.
May 23, 1914.....	do.....	4	4	Abundant well-developed pycnidial stromata on Oct. 13, 1914.
Do.....	Liquidambar.....	4	0	
Do.....	Quercus ¹	4	0	
Do.....	Fagus.....	4	3	
Castanea:				
May 29, 1913.....	do.....	3	3	Pycnospores first observed on Aug. 29, 1913.
Do.....	Liquidambar.....	3	3	Slight indications of pycnidial formation on Aug. 29, 1913; pycnospores on all on Nov. 17, 1913.
Apr. 2, 1914.....	Fagus.....	4	0	
Do.....	Quercus ¹	4	1	Large well-developed pycnidial stromata on Oct. 13, 1914.
Do.....	Castanea.....	4	3	Scattered, fairly well-developed pycnidia on Oct. 13, 1914.
May 23, 1914.....	do.....	4	4	Abundant well-developed pycnidia on Oct. 13, 1914.
Do.....	Liquidambar.....	4	0	
Do.....	Quercus ¹	4	0	
Liquidambar:				
May 29, 1913.....	Fagus.....	3	0	
Do.....	Liquidambar.....	3	3	Pycnospores first observed on Aug. 29.
Sept. 15, 1913.....	Fagus.....	8	5	No evidence of growth until the spring of 1914; pycnidia few and small on Oct. 13.
Do.....	Castanea.....	6	2	No growth until the spring of 1914; pycnidia small on Oct. 13.
Do.....	Quercus.....	6	0	
Apr. 2, 1914.....	Fagus.....	4	0	
Do.....	Quercus ¹	4	0	
Do.....	Castanea.....	4	0	
May 23, 1914.....	do.....	4	0	
Do.....	Liquidambar.....	4	4	Abundant pycnidia on Oct. 13, 1914.
Do.....	Quercus ¹	4	0	
Do.....	Fagus.....	4	0	

¹ The species used in this case was *Quercus prinus*, which proved to be an exceedingly unfavorable host for *Endothia gyrosa*.

Inoculations with *Endothia gyrosa* were also made on numerous hosts from which it had never been reported. Six or more inoculations were made on each host, in the manner described above, except that a part of each series was left unwrapped. The following inoculations showed no growth whatever: Those made in Virginia, April 4, 1914, on *Cornus florida*, *Fraxinus americana*, *Juglans cinerea*, *Ilex opaca*, *Sassafras variifolium*; in Maryland, April 17 and 22, 1914, on *Carya glabra*, *Cornus florida*, *Liriodendron tulipifera*, *Nyssa sylvatica*, *Sassafras variifolium*, and *Quercus alba*; and in New York, July 11, 1914, on *Betula alba*, *Prunus serotina*, *Populus tremuloides*, *Rhus glabra*, *Salix* sp., and *Sassafras variifolium*. On *Acer pennsylvanicum* and *Carya* two out of the six inoculations developed a few stromata. These were found only on the tissue injured by the cut and there was no evidence of parasitism.

On *Castanea*, *Fagus*, *Quercus*, and *Liquidambar*, however, a branch inoculated as described above dies back rather faster than the checks. This would indicate, as suggested by Clinton (18, p. 419), that *E. gyrosa* is a weak parasite; that is, that it is able to invade injured and dying tissue.

It is evident from Table III that *Endothia gyrosa* coming from any of the four hosts named will, under favorable circumstances, grow on any of the others. Several other interesting facts are brought out by the table. Inoculations made with material from *Liquidambar* grew in general more rapidly on *Liquidambar* than on any of the other hosts. In many cases, material from *Liquidambar* failed to grow on *Castanea*, *Fagus*, and *Quercus*, and even when inoculations were successful growth was somewhat slower and pycnidial production less abundant.

On the other hand, inoculations from *Fagus*, *Quercus*, and *Castanea* usually grew less rapidly on *Liquidambar* than on any of the other three hosts. This is, of course, what would be expected from the systematic relationships of the host species, and while the inoculations made are too few to permit any definite conclusions they are nevertheless suggestive. As shown by Table III, *Quercus prinus* proved a very unfavorable host for *Endothia gyrosa*.

In all cases inoculations made in the fall (Sept. 15) failed to show any growth until the following spring. This corresponds with the results in inoculations of *Endothia parasitica*, but it is, of course, impossible to determine whether this failure to grow is due to the dormant condition of the host or to unfavorable weather conditions. Perhaps correlated with the results just noted are the unusually poor results obtained from inoculations made in the early spring. It will be noted that inoculations made on April 2, 1914, were in general much less successful than those made on May 23, 1914, in exactly the same locality and in many cases on the same hosts.

ENDOTHIA SINGULARIS.

The material of *Endothia singularis* distributed by Sydow as *Calo-pactis singularis* was on *Quercus gambellii* Nutt. The writers have seen abundant material on this species as well as specimens on *Q. utahensis* (A. DC.) Rydb., *Q. leptophylla* Rydb., and *Q. nitescens* Rydb. Specimens on the latter two hosts were sent by Bethel, who, in a letter, reports finding this species also on *Q. pungens* Liebm.

All of these species except *Quercus leptophylla* are chaparral-forming shrubs growing at an elevation of 4,000 feet or more. There is at present no evidence that the fungus is parasitic on any of the species.

Inoculations with the mycelium of *Endothia singularis* were made on *Fagus* and on *Quercus alba*, *Q. velutina*, *Q. rubra*, and *Q. palustris*, as well as on *Q. ilicifolia* on Overlook Mountain in the Catskills. No growth has, however, been noted in any case.

ENDOTHIA FLUENS.

When these investigations were commenced, the writers thought that the *Endothia* found in Europe might be the same as *Endothia parasitica* found in America. Inoculations were accordingly made in Maryland during October, 1912, with cultures from material collected on the chestnut by the senior writer at Stresa, Italy, and Etrembieres, Switzerland, using material of *E. fluens* sent by P. J. Anderson from Pennsylvania; also material of that species and of *E. parasitica* collected in Virginia as checks. In this case, as in all others where no special mention is made of the method, inoculations were made by cutting through the bark to the wood with a sharp knife. The inoculating material was then inserted with a freshly cut twig and the wound tied up either with cord or rubber bands. If cord was used it was cut away within two to four weeks. The rubber bands became loosened by exposure to the weather within about the same time.

Inoculations were made with all the above material on sprouts of *Castanea dentata* and *Quercus prinus*. The results are summarized in Table IV.

TABLE IV.—Inoculations of *Endothia* in Maryland in October, 1912.

Fungus.	Host inoculated.	Number of inoculations.	Number showing growth.
<i>Endothia parasitica</i>	<i>Castanea dentata</i>	32	28
Do.....	<i>Quercus prinus</i>	6	0
<i>E. fluens</i> :			
European.....	<i>Castanea dentata</i>	14	14
American.....	do.....	26	23
Do.....	<i>Quercus prinus</i>	12	9

The inoculations were examined every 10 days until December 1 and monthly thereafter throughout the winter. There was no perceptible growth until the last of April, when several of the inoculations of *Endothia parasitica* showed slight sunken areas. By May 20 all inoculations checked as showing growth (last column of table) showed the slight yellowish elevations of the bark which indicate the beginnings of pycnidia. On August 30 all the inoculations of *E. parasitica* checked as showing growth had spread rapidly and attacked the living tissues of the host, producing typical cankers with mycelial fans and abundant pycnidia.

No signs of growth were noted in the inoculations of *Endothia fluens* until about the middle of May, 1913, when most of them showed signs of pycnidium formation. By August 30 all those marked as showing growth had produced characteristic pycnidia with spores, which when cultured proved to be typical *E. fluens*. In no case, however, did this fungus spread for any appreciable distance beyond the injured portion or show signs of active parasitism. These results agree with those given by Anderson and Anderson (2, p. 206) with American material of *E. fluens*, and have since been fully confirmed by further observation.

During the summer of 1914 about 1,100 inoculations of *Endothia fluens* from both European and American sources and of *E. fluens mississippiensis* were made on Castanea sprouts. In no case was there any evidence of active parasitism, as in *E. parasitica*.

Although *Endothia fluens* has been found in Europe on a considerable number of deciduous host plants (as recorded on p. 18), the writers have thus far failed to find it in this country on any except Castanea and Quercus. It seemed possible that the European strain of the fungus might be somewhat more plurivorous¹ in its habits than the American. In order to throw some light on this point, the following inoculations were made:

On March 31, 1914, 10 inoculations were made, half of European and half of American material, at Francis, Md., on the following hosts: *Alnus rugosa*, *Betula nigra*, *Carpinus caroliniana*, *Carya glabra*, *Fagus grandifolia*, *Liriodendron tulipifera*, and *Liquidambar styraciflua*. Pycnidia appeared only on *Carya glabra* and *Carpinus caroliniana*. Of the inoculations which actually produced pycnidia, four on *Carpinus* and three on *Carya*, one of each was the European strain.

On April 22 inoculations were made with American material of *E. fluens* at Kensington, Md., on *Acer rubrum*, *Carya glabra*, *Cornus florida*, *Fagus grandifolia*, *Prunus serotina*, *Quercus prinus*, *Sassafras variifolium*, *Vaccinium* sp.,

¹ This term is proposed to apply to fungi occurring on two or more hosts or substrata and may be applied to all fungi except true parasites. It is derived from *plus* (plur-), more, and *vorare*, to devour. Compare omnivorous already in use for fungi.

The term pleioxonous might be derived from De Bary's proposed word pleioxony and applied to true parasites having the power to invade more than one species of host plant, and the term plurivorous restricted to nonparasitic organisms.

and *Vitis* sp. Of these, *Acer rubrum* and *Carya glabra* gave numerous small pycnidia.

On July 10 the following hosts were inoculated at Woodstock, N. Y., with *E. fluens* from Europe: *Acer rubrum*, *A. pennsylvanicum*, *Carya ovata*, *Corylus americana*, *Fraxinus americana*, *Hamamelis virginiana*, *Kalmia latifolia*, *Populus grandidentata*, *Prunus serotina*, *Rhus glabra*, *Salix* sp., *Sassafras variifolium*, and *Syringa vulgaris*. Each host was inoculated in six or seven places, but all failed to develop except two inoculations on *Acer pennsylvanicum* and one on *Corylus americana*.

The results cited above are so largely negative that they prove very little except that the European strain shows no special affinity for these hosts in America.

ENDOTHIA FLUENS MISSISSIPPIENSIS.

Only five collections of *Endothia fluens mississippiensis* have thus far been made, three on *Castanea dentata* and two on *Quercus* sp. From the results of the inoculations its host relations appear very similar to those of *E. fluens*. The results are shown in Table V.

TABLE V.—Inoculations with *Endothia fluens mississippiensis* on *Castanea* and *Quercus*.

Source of culture.	Host inoculated.	Date.	Number of inoculations.	Number showing pycnidia.
Castanea.....	Castanea.....	Jan. 20, 1912	8	8
Do.....	do.....	May 8, 1913	4	4
Do.....	do.....	do.....	4	4
Do.....	Quercus prinus.....	do.....	9	7
Do.....	Castanea.....	Apr. 18, 1914	12	10
Quercus.....	do.....	do.....	12	10

The inoculations of January 20, 1912, showed no signs of growth until early in May, when the first signs of pycnidium formation were observed. The inoculations with *Endothia fluens mississippiensis* made May 8, 1913, showed within three weeks discolored areas near the cut which were larger than those about the check cuts. On July 25, 1913, all of the inoculations of *E. fluens mississippiensis* marked "successful" showed the beginnings of pycnidium formation. By August 30, 1913, they were producing pycnosporos, which when cultured proved to be *E. fluens mississippiensis*.

Inoculations were made in April, 1914, for the purpose of comparing the material collected on oak with that collected on chestnut. No difference was detected, and there was no indication of active parasitism. This form behaved in this respect exactly as did the *E. fluens* from Virginia both on *Castanea dentata* and *Quercus prinus*.

A series of inoculations parallel to that made with *E. fluens* was made with *E. fluens mississippiensis*. The same hosts were used, and in most cases the dates and places of the inoculation were the same. The results of all that showed any growth are given in Table VI.

TABLE VI.—*Inoculations with Endothia fluens mississippiensis on Acer and Carya.*

Location.	Host.	Number of inoculations.	Number showing pycnidia.
Woodstock, N. Y.....	Acer rubrum.....	6	3
Do.....	Carya glabra.....	6	2
Francis, Md.....	do.....	6	1
Kensington, Md.....	Acer rubrum.....	1	1
Do.....	Carya glabra.....	2	2

As in *Endothia fluens* the growth was confined to the injured tissues, and there was no evidence of parasitism.

ENDOTHIA TROPICALIS.

The material of *Endothia tropicalis* from which the writers secured their cultures, was collected by T. Petch in Ceylon. As the species of *Endothia* in the Northern Hemisphere are chiefly on members of the Fagaceæ, Petch's statements with regard to hosts are of considerable interest. In a letter of March 6, 1914, he writes:

We have no Fagaceæ native in the island. We have introduced various species of *Quercus* and *Castanea*, but subsequent to Thwaite's discovery of this fungus. I do not think there can be any doubt that the fungus is native to Ceylon * * *

Of the specimens now sent * * * those in the packet * * * are from a tree which was producing shoots from the base. This tree is *Elaeocarpus glandulifer* Mast. From the bark and habit, I believe that all my "finds" of *Endothia* have been on this species.

In the accounts of the American chestnut disease, I notice that several authors speak of "cankers," and give their rate of growth. I never see "cankers" (Krebs) on the Ceylon trees. The bark appears to die regularly and smoothly from above downward, and is quite unbroken except for the minute cracks through which the stromata emerge.

Inoculations.—As already noted, ascospores of *Endothia tropicalis* resemble those of *E. parasitica* even more closely than do those of *E. fluens*. This fact, together with its similarity on culture media and its oriental origin, led the writers to fear possible parasitic tendencies.

Inoculation experiments were accordingly made, only on the chestnut and under carefully guarded conditions. In all, about 30 inoculations were made on 2-inch chestnut sprouts, using the methods described for other species.

Of 25 inoculations made in May and June, practically all had developed a few pycnidial stromata by October 20. These stromata were a somewhat brighter orange than those of *E. fluens* or *E. fluens mississippiensis*, and the spores when cultured produced typical *E. tropicalis*. In no case, however, was there any evidence of parasitism.

ENDOTHIA PARASITICA ON HOSTS OTHER THAN CASTANEA.

The first collection of *Endothia parasitica* on a host other than *Castanea* of which the writers have any knowledge is that made by J. Franklin Collins at Martic Forge, Pa., June 30, 1909. As announced by Dr. Metcalf at the Boston (December, 1909) meeting of the American Phytopathological Society, the specimen consisted of a small dead branch of *Quercus velutina* with several spore tendrils typical of *E. parasitica*. This material, which consisted of a terminal branch with leaves still retained, was at once sent to the laboratory at Washington, and cultures obtained from it were subsequently used in making numerous inoculations on *Castanea dentata* on Long Island, N. Y., in July, 1909. On November 17 of the same year, Metcalf reported that the inoculations were entirely successful and had produced typical lesions, thus establishing without question the identity of the fungus.

Fulton (37, p. 53) reports *E. parasitica* on the dead bark of *Quercus alba* and *Quercus velutina*, but found no evidence that the fungus produces in any sense a disease of such trees. Clinton (18, p. 428) mentions "cultures from three different species of *Quercus* and (p. 376) reports specimens on *Quercus alba*, *Q. rubra*, and *Q. velutina*."

Anderson and Babcock, as quoted by Anderson and Rankin (6, p. 564), found *Endothia parasitica* on *Quercus velutina*, *Q. alba*, *Q. prinus*, *Rhus typhina*, *Acer rubrum*, and *Carya ovata*, but it seemed parasitic only on *Quercus alba*. They made inoculations with materials isolated from *Castanea* on *Quercus prinus*, *Q. velutina*, *Q. alba*, *Q. coccinea*, *Rhus typhina*, *Acer rubrum*, *Liriodendron tulipifera*, and *Carya ovata*. Two trees of *Rhus* were girdled and killed by the growth of the fungus. On *Quercus alba* the fungus seemed slightly parasitic, but none of the trees were killed. The fungus grew and produced spore horns on the wounded tissue near the point of inoculation on all the hosts except *Acer* and *Liriodendron*.

Rankin (62, p. 238) also made inoculations with *Endothia parasitica* from *Castanea* on *Quercus prinus*, *Q. rubra*, *Q. alba*, and *Q. coccinea*. He found that the mycelium advanced into the living tissues for a short distance in a few cases, but that in no case were typical cankers formed. Pycnidia were produced abundantly on the injured tissues of all the hosts.

During the course of this work only four specimens of *Endothia parasitica* on hosts other than *Castanea* have come to the writers. One was on chestnut oak (*Quercus prinus*) collected by F. W. Besley, at Towson, Md., December 26, 1911; one from *Quercus velutina*, at Germantown, Pa., as well as one from white oak (*Quercus alba*), at Kennett Square, Pa., were collected by S. B. Detwiler; and one from dead maple, *Acer* sp., at Florence, Mass., by Roy G. Pierce.

The specimen collected by Besley on *Quercus prinus* showed the fan-shaped mats of mycelium typical of *E. parasitica* on *Castanea* species. The fungus had apparently girdled the tree. The specimen on *Quercus alba*, collected by Detwiler, was similar to one on *Quercus prinus* in appearance and came from a dead tree which had apparently been killed by the growth of the fungus. The specimens on *Acer* sp. and on *Quercus alba* were received in the spring of 1914, and cultures isolated from them were used in making inoculations for the purpose of determining whether the fungus had either lost or gained in virulence by passing through other hosts.

INOCULATION EXPERIMENTS.

The cultures secured from *Acer* and *Quercus*, together with one made from *Castanea* at about the same time, were inoculated into three separate sprouts of *Acer rubrum*, *Castanea dentata*, and *Quercus prinus*. The sprouts chosen were of nearly the same size, 2 inches in diameter, and similarly situated, and each was inoculated in five places, with two check cuts above. The inoculations were made the usual way on March 31, 1914, and were examined at least once a month during the summer.

None of the inoculations on *Quercus* produced any growth whatever. On *Acer* the inoculations with the culture from *Quercus* all failed to develop; one of the inoculations with the culture from *Acer* showed a few pycnidia, while four of the inoculations with material from the chestnut developed a few pycnidia. On *Castanea* the three series of inoculations were almost identical, every inoculation producing a typical canker.

Of course, these inoculations are too few to be conclusive, but it is evident that there was no decrease in virulence on the chestnut in passing through *Acer* or *Quercus* and that no particular affinity for either *Acer* or *Quercus* was gained. On the maple, in fact, the culture direct from chestnut produced the most growth.

In addition to those listed above, numerous inoculations were made in order to determine whether *Endothia parasitica* had any parasitic tendencies on other deciduous hosts.

These inoculations were all made during the spring of 1914 by the usual method of cutting well through the bark and inserting mycelium and spores from a pure culture, usually on corn meal. The wounds were then wet, some bound with wet cotton, others with paraffin paper, and about half were left unwrapped.

Seven or more inoculations were made on April 4 in Maryland on *Alnus rugosa*, *Betula nigra*, *Carpinus caroliniana*, *Fagus grandifolia*, *Kalmia latifolia*, *Liriodendron tulipifera*, and *Liquidambar styraciflua*, none of which developed. Inoculations were also made on April

22 in this locality on *Acer rubrum*, *Carya glabra*, *Cornus florida*, *Fagus grandifolia*, *Liriodendron tulipifera*, *Quercus prinus*, *Sassafras variifolium*, *Vaccinium* sp., and *Vitis* sp. without success. On April 18, the following hosts were inoculated in Virginia: *Acer rubrum*, *Betula nigra*, *Benzoin aestivale*, *Carpinus caroliniana*, *Carya glabra*, *Cornus florida*, *Fagus grandifolia*, *Liriodendron tulipifera*, *Prunus serotina*, *Quercus alba*, *Ulmus americana*, and *Vitis* sp. Each host was inoculated in from four to six places. Of these, pycnidia were produced only on *Acer rubrum*, *Carpinus*, and *Liriodendron*. A similar series was made on the same hosts in the same place on May 27. Inoculations on one tree of *Quercus alba* showed undoubted evidence of parasitism and is described below.

On July 9 and 11 from five to fourteen inoculations were made on each of the following hosts at Woodstock, N. Y.: *Acer rubrum*, *Betula alba*, *Carya ovata*, *Fagus grandifolia*, *Fraxinus americana*, *Hamamelis virginiana*, *Juglans cinerea*, *Kalmia latifolia*, *Nyssa sylvatica*, *Ostrya virginiana*, *Populus grandidentata*, *Prunus serotina*, *Rhus typhina*, *Quercus rubra*, *Salix* sp., *Sambucus canadensis*, and *Sassafras variifolium*. Pycnidia appeared on *Acer rubrum* and *Ostrya* only. The fungus made considerable growth on two plants of *Rhus typhina*, partly girdling branches one-half inch in diameter and producing distinct fans. The fans were, however, much smaller than those usually found in *Castanea*. Inoculations were made at Avon, Conn., July 15, on *Acer saccharum*, *Betula alba*, *Carya glabra*, *Cornus florida*, and *Ostrya virginiana*. Pycnidia developed only on *Ostrya*. The successful inoculations with *Endothia parasitica* are shown in Table VII.

TABLE VII.—Successful inoculations in 1914 with *Endothia parasitica* on hosts other than *Castanea*.

Locality.	Date.	Host.	Number of inoculations.	Number successful. ¹
Virginia.....	Apr. 18	<i>Acer rubrum</i>	9	7
Do.....	do.	<i>Carpinus caroliniana</i>	6	2
Do.....	do.	<i>Liriodendron tulipifera</i>	6	1
Do.....	May 27	<i>Quercus alba</i>	4	4
New York.....	July 11	<i>Acer pennsylvanicum</i>	14	4
Do.....	do.	<i>Ostrya virginiana</i>	6	2
Connecticut.....	July 15	do.....	15	4

¹ Inoculations producing pycnidia are classed as successful.

It must be noted that while pycnidia were produced in the cases listed as successful, there was no indication of parasitism, nor did the growth extend beyond the tissue injured by the cut except in *Quercus* and *Rhus*.

Out of about 400 inoculations with *Endothia parasitica* on hosts other than *Castanea*, about 70 of which were made on different

species of *Quercus*, chiefly *Q. prinus* and *Q. alba*, only one case has been noted in which the fungus assumed a typically parasitic rôle. The data in this case may be summed up as follows: Four inoculations were made May 27, 1914, on a small tree of *Quercus alba*. This tree was suppressed, and although when cut down it showed about 30 annual rings it was only 16 feet high and about 2 inches in diameter. It was in a moist, shady locality close beside a stream, and in spite of its small size was apparently healthy. The inoculations were made in the usual way from a culture of *E. parasitica* on corn meal. On August 1 it was noted that all four inoculations were producing pycnidia, and in at least one case typical fans had been developed. On October 15 all four cankers had more than half girdled the seedling. No observations were made during the winter, but at the time the leaves had reached half the normal size, in the spring of 1915, the tree was completely girdled. On July 1 this tree presented an appearance closely similar to that of a small chestnut tree girdled by *Endothia parasitica*. All the leaves above the point of inoculation were dead and remained attached to the branches. Below the girdled portion, water sprouts had developed, as has been frequently described for chestnut trees affected with *E. parasitica*. Cultures made from this tree showed the fungus to be typical of *E. parasitica*. Whether this case of parasitism was due to unusual virulence on the part of the fungus or to unusual susceptibility on the part of the host is, of course, merely a matter of conjecture; the latter alternative seems, however, somewhat more probable, as other inoculations with this strain of the fungus on *Q. prinus* and *Q. alba* failed to show similar results.

In addition to the above, a somewhat similar observation has been made by the writers near Amherst, Mass. In connection with other work, a sprout of *Quercus prinus* about an inch in diameter was inoculated with *Endothia gyrosa* on July 15, 1914. When this inoculation was made the tree was partly (about one-fourth) girdled. *E. gyrosa* developed normally and by October 1, 1914, had produced several pycnidial stromata. No change was apparent when the inoculations were examined in May, 1915.

E. parasitica was abundant in the region, however, and apparently gained entrance through the cuts originally made, for when the plot was next visited, August 17, 1915, the sprout appeared quite dead, though still retaining its full-sized dead leaves. Further examination showed numerous pycnidia of *E. parasitica* in addition to those of *E. gyrosa* near the region of the original inoculation. The pycnidia of *E. parasitica* were on all sides of the stem, while those of *E. gyrosa* were confined to the portion above the cuts made in inoculating. The mycelial fans typical of *E. parasitica* were abundant also. These

observations leave no doubt that the tree was girdled and killed by *E. parasitica*.

Endothia parasitica in exceptional cases undoubtedly attacks other hosts than *Castanea*, producing cankers and sometimes causing the death of the host. The results of the inoculations just recorded appear to indicate that some unusual conditions of host or parasite must obtain in such cases. Whether such a combination of conditions or factors will ever become sufficiently frequent to lead to serious destruction of *Quercus* or other forest trees remains to be determined.

ENDOTHIA PARASITICA ON CASTANEA SPP.

Although found occasionally on species of other genera, *Endothia parasitica* is dangerously pathogenic only on members of the genus *Castanea*. The parasitism of this fungus on the American chestnut (*Castanea dentata*) was first proved by Murrill (57) and has since been demonstrated by numerous investigators.

When *Endothia parasitica* was discovered in the United States it was considered by some investigators to be a native fungus which had suddenly become parasitic, and various theories were advanced to account for the supposed unusual susceptibility of the host. As enumerated by Clinton (18, p. 391), the factors suggested include winter injury, drought injury, fire injury, weakened condition due to continued coppicing, and reduced amounts of tannic acid due perhaps to weather conditions.

Continued study by many investigators in different localities has, however, fully confirmed the observation originally made by Metcalf and Collins in 1910 (53) that "a debilitated tree is no more subject to attack than a healthy one" and that *Endothia parasitica* is actively parasitic on the healthiest specimen of *Castanea dentata* in case there is opportunity for wound infection. The writers have personally made over 1,200 inoculations of *E. parasitica* on *Castanea dentata* without finding a single individual that showed any resistance.

CASTANEA ON LIMESTONE SOILS.

Not only are all trees susceptible, but so far as is known no condition of soil, altitude, or moisture renders them more resistant to the disease. The idea has been held by some writers that chestnuts grown on limestone soils were immune to the disease, and the planting of chestnut orchards on such soils was advocated. This view is held by Gulliver (38, p. 53), who sums up his observations in two regions in Pennsylvania as follows:

In every series of tracts taken from limestone to overlying shale soils, the percentage of blight is least at a comparatively short distance * * * from the edge of the limestone. Tracts on soils derived from limestone which show the highest percentage of blight seem to be those where the soil has

become acid from underground drainage. Chestnut trees on soils derived from other alkaline rocks show less blight than is found in the trees on shale soils with limestone underneath.

On the other hand, Detwiler (24, p. 67) reports observations in the Lizard Creek valley which seem to show that these relations do not always occur. He says—

A belt of limestone borders Lizard Creek valley on the south, and the per cent of infection is as high in that region as elsewhere. Infection centers have been found near limestone quarries, where the roots of the chestnut penetrated to bedrock.

Actual proof or disproof of the truth of this idea was peculiarly difficult, since chestnut is but rarely found growing naturally on calcareous soils. During the summer of 1914, however, a careful study of the chestnut on certain portions of limestone areas in western Maryland and western Connecticut was made. These localities were chosen because they were convenient in connection with other work, the blight had been present for several years in both States, and thorough State geological surveys made the location of the limestone areas very easy. The two States also are sufficiently far apart to eliminate sources of error that might arise from local weather conditions.

In western Connecticut chestnut was abundant on glacial till over the Stockbridge limestone of this region. Chestnut was also growing directly over limestone at various points near Danbury, Twin Lakes, Chapinville, and Lakeville. Several localities near the latter place were kindly pointed out by Dr. George E. Nichols. Near Danbury every tree examined showed the blight in a more or less advanced stage, while near the other towns, all in the northwest corner of the State, nearly 50 per cent of the trees were blighted. About 30 inoculations were made on sprouts in this region, and all except two developed cankers quite as rapidly as did check inoculations made on the trap ridge west of Hartford.

Chestnut is very rare on the Shenandoah limestone in the Hagerstown and Frederick valleys of western Maryland. A number of chestnut trees were, however, located growing on limestone soil near Frederick Junction and Adamstown in the Frederick valley. The disease was already established west of Adamstown, where 20 per cent of the chestnuts were either diseased or dead. Twenty-two inoculations were made on nine chestnut sprouts in these two regions, and all developed typical cankers quite as rapidly as the checks made in similar sprouts growing over Baltimore gneiss 50 miles east.

RECESSION OF THE CHESTNUT IN THE SOUTHERN STATES.

While it has been definitely proved that *Endothia parasitica* is pathogenic on healthy chestnut trees, one of the points brought for-

ward by the advocates of the "weakened host" theory seems to be fully established; that is, that the chestnut trees have suffered severely in the southern Appalachian regions previous to the present epidemic, in some cases being practically exterminated, so that the range is now considerably less than formerly. The evidence on this point has been summarized by Clinton (18, pp. 408-413). Various writers quoted by him cite fire injury and borers and other insects as causes for this recession.

Long (48, p. 8) considers a root rot due to *Armillaria mellea* as "very probably an important factor in the gradual recession of the chestnut" in North Carolina. It seems probable that all of the above-mentioned factors, and perhaps others, have played a part in the destruction of the chestnut in this region.

RELATIVE SUSCEPTIBILITY OF SPECIES OF CASTANEA.

The importance of *Castanea dentata* as a timber and nut tree and its abundance in eastern North America, where the blight is prevalent, has made the chestnut blight an object of much investigation. Descriptions of the nature and importance of the disease, the rate of its spread, methods of distribution, and attempted methods of control have been given in detail by Anderson (1-5), Clinton (12-15), Heald (39-41), Metcalf (51 and 52), Metcalf and Collins (53), Rankin (62), and others. It may be sufficient here to state that the fungus enters the host through a wound in the bark, probably never or very rarely through lenticels or natural cracks, grows chiefly in the cambium, penetrating for only short distances into the wood, and kills the tree or branch by girdling. Once a tree is attacked, it is only a question of time till it succumbs.

The chinquapin (*Castanea pumila*) was found by Murrill (58) in 1908 to be attacked by *Endothia parasitica*. Rogers and Gravatt (65) in 1915 made inoculations of *E. parasitica* on *C. pumila* and found that the parasite grew as rapidly on this host as on *C. dentata*. They attribute the apparent resistance of the chinquapin to its comparative freedom from bark injury, a view also held by other writers. Pantanelli (60) and Metcalf (52) have proved that the European chestnut is readily susceptible to the disease.

The only chestnuts thus far observed which show any resistance to *Endothia parasitica* are those of oriental origin. Metcalf (51) first pointed out the resistance of the Japanese chestnut. This observation has since been confirmed by Clinton (18, p. 375), who "failed to produce the disease in a Japanese variety in the [Conn.] station yard, although the bark was inoculated in 16 different places."

Van Fleet (84), in describing the spread of the chestnut blight in his breeding plats at Washington, D. C., says (p. 21): "The Asiatic chestnuts and the chinquapin-Asiatic hybrids are plainly highly resistant."

Morris (56) sums up eight years' observation of the effect of the chestnut blight on 26 species and varieties of chestnuts at Stamford, Conn., as follows:

Every one of the 5,000 American chestnut trees became blighted * * * None of [the grafted varieties or seedlings of European and Asiatic varieties appear] to be as vulnerable as the American chestnut, but most of mine are now dead. Korean chestnuts and chestnuts from the Aomori regions in Japan resisted the blight until six years of age. Since that time they have shown a marked tendency to blight, but resist it better than does the American chestnut * * * None of the American species of chinquapin * * * has blighted with the exception of two limbs * * * None of the specimens of *Castanea alnifolia* [or] * * * of *Castanea mollissima* has blighted, but these latter include only five trees.

These observations as to the resistance of the oriental varieties of chestnut when grown in America are of particular interest in connection with the observations of Meyer in the region where he discovered *Endothia parasitica* native. In his letter to Fairchild, written from Santunying, China, June 4, 1913, Meyer makes the following notes with reference to the effect of the blight in that region:

This blight does not by far do as much damage to Chinese chestnut trees as to the American ones * * *

Not a single tree could be found which had been killed entirely by this disease, although there might have been such trees which had been removed by the ever-active and economic Chinese farmers * * *

Dead limbs, however, were often seen and many a saw wound showed where limbs had been removed * * *

The wounds on the majority of the trees were in the process of healing over * * *

Old wounds are to be observed here and there on ancient trees.

Meyer's photographs taken near Santunying substantiate his statements. Certainly no specimens of *C. dentata* in a blight-infested region in this country could survive to the age of the Chinese chestnuts shown in his photographs.

That the Chinese chestnuts are by no means uniformly resistant, however, is clearly shown by Meyer's later notes. On the label of a package of *Endothia parasitica* collected on chestnut at Tachingko, Shantung, China, March 21, 1914, he writes, "Trees very severely attacked, many dying off," and in a letter written from the same place he says, "A serious canker; many of the trees here were killed by it."

Further evidence that the virulence of *Endothia parasitica* on Chinese chestnut differs in different parts of China is found in subsequent communications from Meyer. From a point near Chingtsai, Chekiang, China, on July 15, 1915, he writes: "All around Hangchow and west of it one finds the chestnut trees seriously attacked by this destructive bark fungus."

On July 11, 1915, near Changhua, Chekiang, China, he comments, "With the exception of near Taianfu, Shantung, chestnuts

are much more severely attacked in the Chekiang Province than either in Chihli, Shansi, or Shensi. Could the greater humidity of central China be of assistance to a more vigorous development of this destructive fungus?"

COMPARISON OF HOST RELATIONS.

It will be seen from the above description of the host relations of the various species that while some other members of the genus (*E. gyrosa*, e. g.) may have slight parasitic tendencies, *Endothia parasitica* alone is an active parasite. The contrast is still more striking in the section of the genus to which *E. parasitica* belongs, for *E. fluens* and *E. fluens mississippiensis*, which resemble *E. parasitica* so closely in their morphological characters, and to a less degree on culture media, and are common on *Castanea*, are almost purely saprophytic. This fact is established by the work of Anderson (2), Clinton (18), and others, and by two years' field observations and several thousand inoculations made by the writers and their colleagues.

The host relations of the parasite are equally striking. Although *Endothia parasitica* is so pathogenic on *Castanea dentata* that this tree has been practically exterminated over several hundred square miles of its natural range and its extinction is threatened, the fungus has been only occasionally found as even a weak parasite on the closely related genus *Quercus*, and never, to the writers' knowledge, on *Fagus*.

During the course of this work the writers have been continually impressed with the possibilities of a physiological study of *E. parasitica* and one or more closely related species which might throw some light on the fundamental question of the nature and cause of parasitism. No other case is known to the writers of a virulently parasitic fungus and a closely related purely saprophytic one which will grow readily and fruit on a large variety of artificial media, which are readily distinguishable on those media, and remain constant for hundreds of generations.

SUMMARY.

The pathological and economic importance of this group of fungi was first recognized when the chestnut-blight fungus was discovered in New York in 1904.

This organism was first referred to the genus *Diaporthe*, but was later shown to belong to the genus *Endothia*.

The specific identity, relationships, and native home of this parasite were at first uncertain. Some pathologists considered it a native organism which was attracting attention and causing injury chiefly

by reason of the weakened condition of the chestnut trees. Others believed it to be of foreign origin. Its recent discovery in China and Japan has settled this question.

To determine positively the identity of the organism, a thorough study was made of the types or authentic specimens of all the species of *Endothia* obtainable. As a result of this work a revision of available species of the genus is presented. This is based upon the field and laboratory study of over 600 collections. Over 4,000 cultures have also been studied.

Endothia gyrosa (Schw.) Fr. is the type of the genus, which is naturally divided into two sections, chiefly by the character of the ascospores. In section 1 they are short, cylindric to allantoid, and continuous or only pseudoseptate. This section contains two species, *E. gyrosa* and *E. singularis*.

Section 2 has oblong-fusiform to oblong-ellipsoid uniseptate ascospores. This contains four species and one variety, *Endothia fluens*, *E. fluens mississippiensis*, *E. longirostris*, *E. tropicalis*, and *E. parasitica*. *E. tropicalis* is a hitherto unrecognized species.

Radiating layers of yellowish or buff mycelium situated in the bark and cambium of the host are found to be constant and distinctive characteristics of *Endothia parasitica*. None of the other species studied shows this character.

All species of the genus possess a stroma having a distinctive yellow to reddish color.

There is no division of stroma into distinct layers, as described by some authors. Pycnidia or perithecia may arise in any portion of the stroma. Most commonly where pycnidia and perithecia are both present the pycnidia are above the perithecia, though the reverse arrangement is sometimes observed and all intermediate conditions frequently occur.

The stromata of the species of section 1 are larger, more erumpent, and contain more numerous pycnidia than those of section 2. *Endothia singularis* is especially striking in this respect. The stromata of section 2 are smaller and very similar in all the species.

The pycnidia consist of more or less irregular chambers or locules in the stroma.

The pycnospores are small in most species and furnish no very distinctive specific characters. The pycnospores of *Endothia tropicalis* are, however, constantly larger and more variable in size than those of the other species.

Paraphyses have been described by some authors, but have never been observed by the writers.

The ascospores in the species of section 1 are very similar in size and shape. Those in section 2, though similar, have been found by thorough study and careful measurement to show constant though

slight differences, as indicated in the tables of measurements and ratios.

Numerous cultures of all the species on a variety of media show that each species has constant and distinctive characters of growth and color.

All the species grew equally well in light or darkness, and no decided differences in temperature relations have been demonstrated.

The species appear to have well-defined geographic limits of distribution, which have been approximately determined for the American species. The distribution of the species does not coincide with that of the hosts, but seems to be determined in part by soil and climatic conditions.

Endothia fluens has the widest distribution, being frequent and widely distributed in Europe and the eastern United States, and also occurring in Asia.

Endothia parasitica is evidently of oriental origin. Specimens have been received from five rather widely separated localities in China and from two localities in Japan. In the eastern United States it is now abundant from Maine to North Carolina and is rapidly spreading south and west. It has already destroyed most of the chestnut trees within a radius of 100 miles of New York City.

The species have rather definite host relations.

Endothia gyrosa has been found on five genera of plants, viz, Castanea, Fagus, Liquidambar, Quercus, and Vitis.

Endothia singularis occurs, so far as known, only on Quercus species.

Endothia fluens has been found in America only on Castanea and Quercus, but in Europe it occurs on Alnus, Carpinus, Castanea, Corylus, Quercus, and Ulmus, and has been reported on Aesculus, Fagus, and Juglans.

Endothia fluens mississippiensis has been found only on Castanea and Quercus.

Endothia tropicalis is known only on Elaeocarpus.

Endothia parasitica has been found on Acer, Carya, Castanea, Quercus, and Rhus, but at present is only known as a serious parasite on Castanea.

Upon the American species of Castanea it is actively parasitic under all the conditions of soil and climate observed. Oriental species of chestnut are more or less resistant to the disease both in America and their native homes.

None of the species except *Endothia parasitica* has thus far been found to be actively parasitic.

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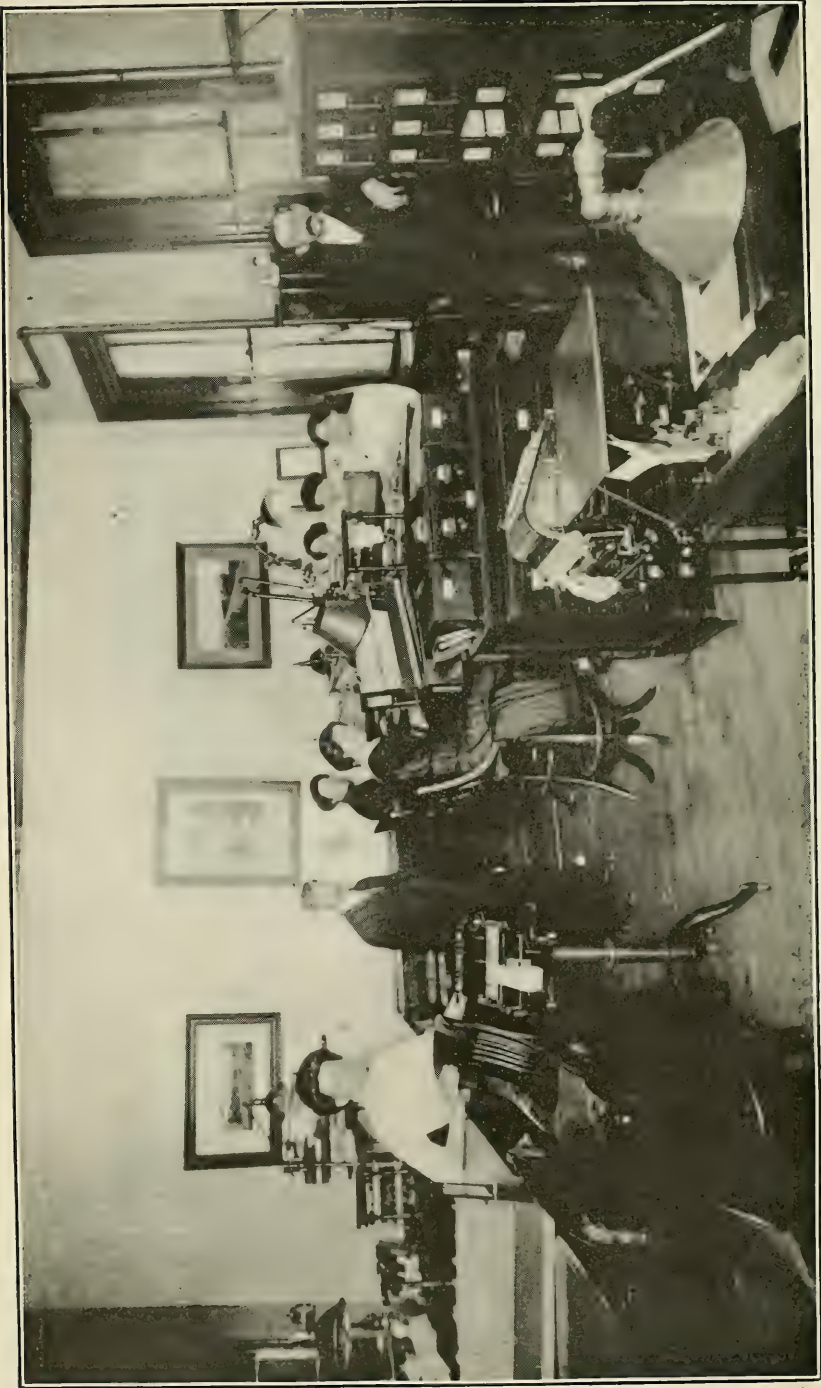
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BUSINESS PRACTICE AND ACCOUNTS FOR COOPERATIVE STORES.

By J. A. BEXELL, *Dean, School of Commerce, Oregon Agricultural College, Collaborator, Office of Markets and Rural Organization;* and W. H. KERR, *Investigator in Market Business Practice, Office of Markets and Rural Organization, U. S. Department of Agriculture.*

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INTRODUCTION.

The purpose of this bulletin is to outline a simple and adequate system of records for cooperative retail stores, and to point out such fundamental business methods as must be observed to insure success. It is not a treatise on the principles of bookkeeping, but merely an outline of a special system adapted to a cooperative business. It

NOTE.—This bulletin should be of interest to all cooperative stores and members of such stores. It should be of interest to retail grocery and general merchandise stores throughout the country.

is assumed that no corporation will engage in business without employing a competent bookkeeper.

In a large percentage of business failures the cause can be traced directly to defective methods of analyzing the business through the absence of carefully kept records.¹ No business can hope to succeed unless its condition is kept constantly before the management in the form of comparative statistics upon which future operations may be based.

It is important that the system of accounts be adapted to the business in hand. It should be as simple as circumstances permit, but it must be adequate for the analysis of every phase of the business; the results must be capable of proof by means of double entries, and the facts must be available at all times to the management.

The form of accounting records depends largely upon the information desired and the character of the business they serve. It is poor economy to sacrifice completeness and real usefulness for simplicity. Under no circumstances should a system of accounts be adopted until it is certain to meet every demand for information that may be made on it.

It is impossible to exaggerate the importance of selecting a proper system of accounts. By "system" is meant, not a disconnected mass of notes and memoranda, but a scientific *analysis* of the business. Nor should the value of standardization of accounts be overlooked. One of the greatest arguments in favor of adopting a uniform system of accounts is to enable managers to draw comparisons between theirs and other stores and groups of stores.

The only essential difference between accounting for cooperative and other retail stores lies in the fact that the former are semipublic institutions, while the latter are private enterprises. In the cooperative store the working capital is contributed by a large number of persons, who are entitled to regular reports. The business is managed by a board of directors, which requires constant information concerning the conduct of the business. The law creating the association prescribes certain methods of publicity. Moreover, the accounting for cooperative associations is complicated by the fact that the net earnings are usually distributed to patrons, frequently to both members and nonmembers, in proportion to their purchases from the store.

In every corporation organized for profit there are two distinct classes of records: First, those pertaining to its corporate existence, including its articles of association, by-laws, and the minutes, the capital contributions of its members, the distribution of dividends, and the like; and, second, the records of operation, or trade, and the relation of the business to the public.

¹ Kerr, W. H., and Nahstoll, G. A. Cooperative organization business methods. U. S. Dept. of Agr. Bul. 178. 1915.

CORPORATE RECORDS.

MINUTES.

The minutes should constitute a faithful record of all important documents, such as the articles of association and by-laws, as well as, a complete record of every meeting of the association. They should be kept in perfect chronological order, every record properly dated and indexed. Nothing should be entered on the minutes until it is properly acted upon by the association, and, as evidence of such action, in every case the minutes should be countersigned by the president. Form 1 will be found convenient.

Form 1.—MINUTES.

June 1, 1915.

Minutes of a preliminary meeting of citizens of ——— interested in the organization of a cooperative store.	Preliminary meeting.
The following members of Union No. — met in ——— at ———, June 1, 1915, at 3 o'clock.	Place. Time.
There were present A, B, C, D, etc.	Attendance.
Mr. John Doe was elected chairman and Mr. James Smith secretary.	Officers.
After considerable informal discussion, the following resolutions were unanimously adopted:	Resolutions.
(1) That it is the sense of the meeting that a cooperative association should be organized for the purpose of conducting a retail store of general merchandise.	Cooperative store to be started.
(2) That a committee of three be appointed to make a preliminary canvass for membership, and to report at the next meeting.	Membership committee.
(3) That a committee of three be appointed to take the necessary preliminary steps toward organization, and to report at the next meeting.	Committee on constitution and by-laws.
(4) That the committee on organization be authorized to employ legal counsel in drafting the articles of association and by-laws and in perfecting the organization.	Legal counsel for organizing.
The meeting adjourned at 5 o'clock, to meet at the same place at 3 o'clock, June 8, 1915.	
Approved: <i>John Doe,</i> <i>Chairman.</i>	Attest: <i>James Smith,</i> <i>Secretary.</i>

June 8, 1915.

Pursuant to adjournment at the preliminary meeting held June 1, a meeting of persons interested in the establishment of a cooperative store, was held in ———, ———, at 3 o'clock.

The meeting was called to order by Mr. Doe. Mr. Smith acted as secretary.

The minutes of the meeting of June 1 were read and approved.

The committee on membership reported that 60 persons had subscribed to a total of 75 shares or \$1,875. The report was adopted and ordered placed on file. [Here follows a copy of the report, including the subscription list.]

The committee on organization submitted its report, and after due deliberation the following Articles of Association were adopted and ordered filed with the proper authorities. [Here follows a copy of the document as adopted.]

The organization committee was directed to act with the legal counsel in securing the incorporation certificate.

The meeting adjourned to meet at the same place at 3 o'clock June 22, 1915.

Approved:

John Doe,
Chairman.

Attest:

James Smith,
Secretary.

Officers.

Report of membership committee.

Report of committee on organization. Constitution.

Organization committee to cooperate with counsel.

Adjournment.

The minutes of the board meetings should have the same general form, and should be a faithful record of every important act of that body.

The reader should observe the marginal notations. They are the important points to be indexed. A good alphabetical index should accompany the minutes, which should note such items as are likely to be referred to frequently.

Form 2.—SUBSCRIPTION AGREEMENT.

We, the undersigned, do hereby subscribe, each respectively, for the number of shares of the Capital Stock of the Farmers' Cooperative Association set opposite our respective names, and do agree to pay for such shares the par value thereof, to wit: Twenty-five Dollars (\$25) for each share of stock so subscribed, at such time and in such manner as may hereinafter be directed by the Board of Directors of the said Farmers' Cooperative Association.

And we do hereby fix the 8th day of June, A. D. 1915, at the hour of 3 o'clock in the afternoon of said day, as the time, and the office of as the place for holding the meeting of subscribers to the Capital Stock of the company, and do hereby waive statutory or other notice of time, place, and purpose of said meeting, and do hereby consent to any and all business which may be transacted thereat.

No.	Name.	Address.	Shares.	Amount.
1	John Doe	762 Jefferson	2	\$50.00
2	.....	.....	.....	.....

145	Richard Roe	2531 Monroe	1	25.00
	Total .....	.....		6,000.00

Form 3.—STOCK NOTE.¹

No. 376.

FARMERS' COOPERATIVE ASSOCIATION.

\$25.00

[Place] June 10, 1915.

Payments.			
Date.		Amount.	
Oct.	1	10 00	
Jan.	5	10 00	
May	1	5 00	
Total		25 00	

In consideration of the Certificate of Membership in the Farmers' Cooperative Association, the receipt of which is hereby acknowledged, I agree to pay the said association within *one year after date* at their office in, or to its order, the sum of *Twenty-five no/100* Dollars, with interest thereon at the rate of six per cent per annum from date of issue until paid.

Due June 10, 1916.

B. S. Brown

Address: R. F. D. No. 4.

It is understood and agreed that Stock Certificate No. covering shares is held by the Association as collateral for this note, pending payment in full.

¹ In this system of accounts provision is made for recording stock notes because a large number of associations have accepted such notes as temporary settlement for stock. The practice is not recommended, however, since there seems to be no good reason why cash payment should not be required. Where notes are accepted the corresponding stock certificate must be held as collateral, as shown in Form 3.

Form 4.—STOCK CERTIFICATE.

No. 458

Incorporated Under
the Laws of the
State of —

Shares 2

FARMERS' COOPERATIVE ASSOCIATION.

[Place]

This Certifies that *F. R. Jones* is the owner of *Two* Shares of Capital of the par value of Twenty-five Dollars (\$25.00) each, of the

FARMERS' COOPERATIVE ASSOCIATION,

transferable only on the books of the Association by the holder in person, or by attorney, upon the surrender of this Certificate properly endorsed.

In witness whereof, the said Association has caused this Certificate to be signed and sealed by its duly authorized officers this 2 day of *January*, A. D. 1916.

[SEAL.]

James Smith,
Secretary.

John Doe,
President.

Form 5.—STOCK CERTIFICATE REGISTER.

Cert. No.	Date issued.		Name.	Address.	L.F.	Shares.	Amount.
458	June	20	<i>F. R. Jones</i>	<i>R. F. D. 4</i>		2	50
459	1915	20	<i>F. L. Green</i>	<i>830 Monroe Street</i>		2	50
.....							

						238	6,000
			<i>Total for year</i>				

Left side.

FARMERS' COOPERATIVE ASSOCIATION.

Original Date.	Transferred from—		Original certificate No.	Original number of shares.	Number of shares transferred.	Remarks.
<i>July</i>	<i>5</i>	<i>P. D. Smith</i>	<i>327</i>	<i>2</i>	<i>2</i>	.....
						<i>Cash</i>
						

--	--	--	--	--	--	--

Right side.

It will be assumed that the organization is now completed; that the capital is fixed at \$10,000; that 60 per cent of the capital is issued, 25 per cent paid in, and the balance, \$3,500, is covered by bankable stock notes. The total of the subscription agreement (Form 2) is then \$6,000, and the total of the stock certificate register (Form 5) \$6,000. The manager's first entry in the Journal is shown in Form 19 and the notes are listed in the Stock Notes Register (Form 24).

According to the subscription agreement there were 145 signatures; 90 had subscribed for 1 share each, 25 for 2, 20 for 3, and 10 for 4 shares each. Thirty-five hundred dollars of the subscriptions are yet unpaid, but are in the form of bankable notes (Form 3), and they are entered in the Stock Notes Register (Form 24).

CERTIFICATE BOOK.

The Certificate Book is merely a number of stock certificates and their stubs bound together. The secretary issues the certificates, fills in the stubs, and secures the member's receipt when the certificate is delivered (Form 4). Of course the certificate is signed and sealed as required by law. If for any reason a certificate is canceled, or, if transferred, the secretary requires the return of the certificate, cancels it, and pastes it to its stub.

STOCK CERTIFICATE REGISTER.

The Stock Certificate Register is merely a numerical list of the certificates issued, where all the essential facts noted on the certificate are recorded in logical order. Care should be taken to see that all the certificates are accounted for. The right-hand page is devoted to a record of the facts regarding transfer. Form 5 will be found convenient.

DIVIDEND REGISTER.

After the amount and contents of each envelope (Form 11) have been checked, the total is entered in the proper space in the Trading Summary and Dividend Register (Form 12), and the total from this summary is posted to the Membership Ledger account (Form 6).

The Dividend Register can be arranged in book form, as shown, or in the form of a card file. The book has the advantage of showing a large number of facts on a page, while the cards are more convenient for reference.

MEMBERSHIP LEDGER.

It will be noticed that the Membership Ledger (Form 6) is really two books in one. Each account contains a record of the paid-up stock and transfers, and, finally, the interest and dividend account, the latter being of value chiefly for statistical purposes and in the adjustment of dividends. The amount of the customer's purchase is taken from the "total" column of the Trading Summary and

Form 6.—MEMBERSHIP LEDGER.

Name..... Address..... No.....

STOCK CERTIFICATE ACCOUNT.

[illegible]

Upper half of sheet.

Dividend Register (Form 12). The Membership Ledger is a classification of the information found in the Certificate Register under the several membership accounts. The ordinary form of Stock Ledger on the market is not convenient because of the trade-dividend feature noted above; hence the special form shown in Form 6 is recommended.

INTEREST AND DIVIDEND ACCOUNT.

Most cooperative stores pay interest on their share capital, and their aim is to pay dividends on the purchases. After the total interest or dividends has been ascertained and declared by the board of directors a check for the amount is drawn and recorded in the Cash Book. This check should be deposited to the credit of a special Dividend Account. Dividend checks are drawn for the amounts due members and listed in the Trading Summary and Dividend Register.

Form 7.—MANAGER'S REPORT.

December 31, 1915.

PART I.—BALANCE SHEET.

RESOURCES:		Exhibit.		
11	Cash on Hand	A	150 00	
2	Cash in Bank	A	2,240 00	2,390 00
3	Accounts Receivable	B	7,500 00	
4	Less Reserve for Bad Debts		350 00	7,150 00
5	Bills Receivable	C	2,300 00	
6	Stock Notes Receivable	D	3,240 00	5,540 00
7	Accrued Interest	C		31 00
8	Merchandise Inventory	E		14,900 00
9	Office Supplies	F		20 00
10	Furniture & Fixtures	G	1,560 00	
11	Less Reserve for Depreciation		285 00	1,275 00
12	TOTAL RESOURCES			31,306 00
LIABILITIES:				
13	Accounts Payable	H		1,600 00
14	Bills Payable	I		1,900 00
15	Accrued Interest	I		21 00
16	Coupons Outstanding			150 00
17	Capital Stock			15,350 00
18	Surplus Jan. 1, 1915		9,055 00	
19	Net Profit for Year		6,032 00	
			15,087 00	
20	Less Interest on Stock 657.00			
21	Less Dividends Paid 2,145.00		2,802 00	
22	Surplus December 31, 1915			12,285 00
23	TOTAL LIABILITIES			31,306 00

¹ For explanation of the item, see the corresponding numbers beginning on p. 36.

Form 7.—MANAGER'S REPORT—Continued.

PART II.¹—INCOME SHEET.

A.—TRADING STATEMENT.

SALES:					
24	Gross Sales		76,130 00		
25	Less Returns & Allowances on Sales		200 00		
26	Net Sales				75,930 00
COST OF MERCHANDISE SOLD:					
27	Inventory Jan. 1, 1915	10,300.00			
28	Merchandise Purchases (Exclusive of Discount)	60,100.00			
29	Produce	<u>7,200.00</u>	67,300.00		
30	Accounts Payable Dec. 31, 1915		1,600.00		
31	Freight, Express & Cartage		<u>600.00</u>		
32	Gross Merchandise Cost		79,810 00		
	Deduct:				
33	Inventory Dec. 31, 1915	14,900.00			
34	Accounts Payable Jan. 1, 1915	2,100.00	17,000 00		
35	Net Cost of Merchandise Sold (turnover)				62,800 00
36	Gross Trading Profit				<u>13,130 00</u>
	Notes:				
	Average Inventory (26) and (31)		12,600 00		
	Stock Turns (33) divided by average inventory 5.0 times				
	Cost equals 82.7% of Sales				
	Gross Trading Profit equals 17.3% of Sales.				

¹ The two statements included in this part are shown in detail for the purpose of indicating the method of obtaining the desired information. It is often more satisfactory to present the income sheet to the membership in a more condensed form.

PART II.—INCOME SHEET—Continued.

Form 7.—MANAGER'S REPORT—Continued.

B.—PROFIT AND LOSS STATEMENT.

PROFITS:				
37	Gross Trading Profit		13,130 00	
38	Merchandise Discount		790 00	
39	Interest Received		187 00	
40	Unclassified Income		175 00	14,282 00
LOSSES:				
Buying and Selling Expense:				
41	Salaries & Wages	4,110. 00		
42	Advertising & Wages	150. 00		
43	Delivery	135. 00		
44	Miscellaneous	60. 00	4,455 00	
Management Expense:				
45	Management & Office Salaries	1,440. 00		
46	Office Expense	147. 00		
47	Premiums on Surety Bonds	50. 00	1,637 00	
Fixed Charges and Upkeep:				
48	Rent, Insurance & Taxes	1,290. 00		
49	Light, Heat, Water & Power	173. 00		
50	Depreciation on Furniture & Fixtures	155. 00		
51	Repairs	160. 00		
52	Telephone	50. 00	1,828 00	
Miscellaneous Expense:				
53	Interest on Notes	90. 00		
54	Bad Debts	200. 00	290 00	
55	Total Operating Expense		8,210 00	
56	Unclassified Losses		40 00	
57	Total Losses			8,250 00
58	Net Profit for the year, carried to Surplus			6,032 00
Notes:				
Buying & Selling Expense		5.9%	of Sales	
Management Expense		2.2%	of Sales	
Fixed Charges & Upkeep		2.4%	of Sales	
Miscellaneous Expense		.4%	of Sales	
Total Expenses		10.9%	of Sales	

Form 7.—MANAGER'S REPORT—Continued.

PART III—EXHIBITS.

EXHIBIT A.—CASH STATEMENT.

CASH RECEIPTS:

Cash on Hand January 1, 1915	100 00	
Cash in Bank January 1, 1915	2,480 00	2,580 00
Coupons Issued		12,390 00
Merchandise Sales		34,900 00
Accounts Receivable		35,475 00
Bills Receivable		4,560 00
Bills Payable		13,000 00
Interest Received		180 00
Capital Stock		2,050 00
Stock Notes Receivable		3,400 00
Unclassified—Furniture & Fixtures (Safe)	125 00	
Commission on Machinery Sales	178 00	303 00
		108,838 00
Returns & Allowances	30 00	
Coupons Redeemed	19,600 00	19,630 00
Total Cash Receipts		89,208 00

CASH PAYMENTS:

Merchandise Purchases		60,100 00
Produce Purchases		7,200 00
Returns & Allowances		90 00
Freight, Express, & Cartage		600 00
Salary & Labor		5,550 00
Advertising & Delivery		285 00
Miscellaneous Buying & Selling Expense		60 00
Office Expense		150 00
Rent, Insurance, & Taxes		1,290 00
Light, Heat, Water, & Power		173 00
Interest on Stock	657 00	
Interest on Notes Payable	98 00	755 00
Telephone & Telegraph		50 00
Bills Payable		15,800 00
Furniture & Fixtures		350 00
Unclassified—Dividends Members	1,760 00	
Dividends Nonmembers	385 00	2,145 00
Manager's Bond		50 00
Repairs		160 00
		2,355 00
		94,808 00
Merchandise Discounts	790 00	
Coupons Issued	7,200 00	7,990 00
		86,818 00
Cash on Hand December 31, 1915	100 00	
Cash in Bank December 31, 1915	2,290 00	2,390 00
		89,208 00

Form 7.—MANAGER'S REPORT—Continued.**PART III.—EXHIBITS—Continued.**

B	Accounts Receivable				
C	Bills Receivable and Accrued Interest				
D	Stock Notes Receivable and Accrued Interest				
E	Merchandise Inventory				
F	Office Supplies Inventory				
G	Furniture & Fixtures Inventory				
H	Accounts Payable				
I	Bills Payable and Accrued Interest				
J	Capital Stock				

Form 8.—COMPARATIVE STATEMENT.

Year.	Sales.	Per cent expense.	Per cent salary and labor.	Per cent net profit.	Per cent gross profit.	Average inventory.	Stock turns.	Surplus.	Per cent dividend.
1910	67,074	12.2	7.8	4.0	16.2	16,060	3.5	2,010	2
1911	70,300	12.1	7.5	4.9	17.0	15,350	3.8	4,800	2
1912	79,509	11.4	7.2	6.5	17.9	15,940	4.1	8,300	3
1913	101,600	11.3	6.9	8.1	19.4	18,630	4.4	13,400	5
1914	96,300	12.3	8.0	8.0	20.3	17,870	4.3	18,200	5
1915	111,200	11.9	7.4	10.1	22.0	17,190	5.1	24,900	6

Form 9.—INVENTORY.

Sheet No. 15.	Date Dec. 31, 1914.	Folio 29.
Called by W. J.	Department Groceries.	Priced by L. D.
Entered by J. A.		Extended by W. J.
		Examined by B. W.

Quantity.	Item.	Price.	Extension.	
50 sks	Phillips Best	1.20	60	

STATEMENTS AND REPORTS.

The by-laws of cooperative associations usually specify a number of reports to be submitted at stated intervals by the officers to the board or to the association. Nothing will establish a greater degree of confidence than full, accurate, and regular publicity. The records outlined in the following pages satisfy all these requirements, if properly kept up. They enable the manager to furnish information at a moment's notice on every phase of the business; they contain double-entry checks sufficient to insure protection against errors and negligence; and, if the instructions are faithfully carried out, there is no reason why any reasonable demand on the bookkeeper for infor-

mation should not be met promptly. The reports usually required are: (1) The Manager's Financial Report; (2) the Auditor's Report, and (3) the President's Report.

MANAGER'S REPORT.

The Manager's Report is the foundation of the operating record. It should constitute a complete summary of the financial operations of the past year, month, or other period, as the case may require. Once its form is determined and what information it is to contain, the records must be shaped so as to yield the information with the least labor and liability of error. It should be based entirely on the permanent and balanced records, and on the actual inventory, or on the estimated inventory based on known percentages as explained below under "Inventory."

This implies that the manager must not undertake to prepare his report until the books are completely balanced. It behooves the board, therefore, to allow a sufficient time between the close of the fiscal period and the meeting of the board or members to enable the bookkeeper, the manager, and the auditor to fulfill these conditions. Two weeks will not be found excessive.

The form of the report is very important, since upon this to a large extent depends its value to the directors and stockholders. Form 7 will be found satisfactory. It consists of three parts, viz:

Part I. The Balance Sheet, showing the Resources and Liabilities.

Part II. The Income Sheet, showing:

- (a) The Trading Statement, and
- (b) the General Losses and Gains.

Part III. The Supporting Exhibits, showing the details of the items in I and II.

INVENTORY.

At this point it seems fitting to add a word of caution regarding the inventory. Once or, if time permits, twice a year stock should be taken and the actual market value of the merchandise and the replacement value of the fixtures ascertained. The utmost care should be exercised in taking the inventory, since a difference of several hundred dollars may be found in the Income Sheet by carelessness in measures, prices, and extensions. There are several excellent stock forms of inventory blanks on the market. A conservative allowance for depreciation of goods, due to age or changes in style, price, etc., should be made, so that the inventory stands for the actual market value of the stock. Form 9 will be found satisfactory.

If an audit is made monthly or at any other time between the actual inventories, an approximate value of the goods may be found by the following formula: The last actual inventory (27),¹ plus the merchandise cost (32), minus the net cost of the sales (35). The latter is found

¹ Numbers refer to same items in Manager's Report, page 10.

by subtracting the percentage of gain, based on the last accurate rate of profit (58), from the net sales. Thus, if the net sales were \$20,000 for the three months after the last statement, and the net purchases \$15,000, the approximate inventory, based on the last gross trading profit (17.3 per cent), would be \$14,900 plus \$15,000, or \$29,900—less 82.7 per cent of \$20,000, or \$16,540—and the inventory would be \$13,360.

AUDITOR'S REPORT.

The importance of the Auditor's Report is often overlooked. It should be directed to the stockholders and contain (1) a certificate of the condition of the books and office methods, whether or not they agree with the report, and (2) recommendations for improvement in any phase of the business. It should be read by the auditor himself, or by the secretary, immediately after the Manager's Report, and should be adopted and spread on the minutes. If the Manager's Report is printed for distribution among the members, the Auditor's Report should be published also. It is quite impracticable to give even a general form of an Auditor's Report, since this will vary greatly according to circumstances. Frequently the auditor analyzes the Manager's Report by means of comparative summaries and graphs (Form 8).

The percentages shown in the merchandise and expense statements may be truly called the barometers of the business. They should be the object of constant study by the management. Not only should the current figures be studied, but they should be compared month by month and year by year. This is accomplished by the Comparative Statement (Form 8). A graphic representation of the various sets of figures may be very profitable. Regarding the duties of the auditor and methods, see page 50.

PRESIDENT'S REPORT.

It is an excellent practice to require an annual written report from the president as a part of the permanent record of the association. This requirement will often stimulate greater activity in the board at a corresponding profit to the association. The report should contain (1) a review of the activities of the board and actions at previous meetings; (2) a recapitulation of the financial operations of the year; (3) a tentative budget for next year's operations; (4) recommendations respecting the policy of the association; and (5) any other matter which, in the opinion of the president, should come before the annual meeting. The summary of last year's business and the budget, of course, should be based on the manager's and auditor's reports. Hence, the *audited* report should be in the hands of the president before his report is prepared. The president or the secretary should read the report to the stockholders, by whom it should be approved and ordered filed or spread on the minutes. The stockholders then proceed to act on the suggestions.

Form 10.—CASH REGISTER TICKET.

Sale No. 5632 Date, Jan. 2, '15 Amount, 1.00	Farmers' Cooperative Association Trade with Yourself. Return this ticket before the tenth day of next month as a claim for dividends.
Subject to Dividend. Name, James Green. No. 58	
Front.	Back.

Form 11.—ENVELOPE SHOWING MONTHLY RETURN OF CASH TICKETS.

Name, James Green												No. 58	
Month, January, 1915.													
Total	Secure a cash register ticket for each purchase, including purchases in exchange for produce on coupons. List the tickets in the columns below. Extend the total and return the envelope containing the ticket not later than the tenth of each month. List each month on a separate envelope.												
	1	2	3	4	5	6	7	8	9	10	11	12	13
	1	1	1	1	1	1	1	1	1	1	1	1	1
	10	15	20	25	30	35	40	45	50	55	60	65	70
	80	85	90	95	1.00	1.05	1.10	1.15	1.20	1.25	1.30	1.35	1.40

Form 12.—TRADING SUMMARY AND DIVIDEND REGISTER.

No.	Name.	Jan.	Feb.	Mar.	Apr.		Total.	Dividend 5 per cent.
58	J. Green.....	30.00	25.00	27.00	34.00		350.00	17.50
75	F. Jones.....			32.00	40.00		586.00	19.30
76	J. Smith.....	15.00	18.00	24.00	14.00		240.00	12.00
Total.....							5,000.00	2,500.00

Form 13.—DAILY SUMMARY OF RECEIPTS.

No. 376		DATE <i>January 2, 1915</i>	
ACCOUNTS.	REMARKS.	AMOUNT.	
Debit:			
(1) 1 Total Cash Received	As per register	435	30
2 Returns & Allowances			
3 Coupons Redeemed		38	00
TOTAL		473	30
Credits:			
4 Coupons Sold		45	00
5 Merchandise Sales		179	00
6 Accounts Receivable	John Jones 6.70; Sam Hill 6.80		
	R. S. White 8.30	21	80
7 Bills Receivable	R. K. Wright	100	00
8 Bills Payable			
9 Interest Received		2	00
10 Capital Stock			
11 Stock Notes			
12 to 17 [Insert titles if the	columns are needed]		
18 Unclassified	Safe sold 125.00		
	Stamps sold .50	125	50
TOTAL		473	30
Register Reading	\$435.82		
Cash Short	\$.52	Approved:	
Cash Long	\$		
Number of Customers	236	J. B. Doe	
Coupons Issued for		Manager	
Produce	\$		

Prepared in duplicate.

¹ These numbers correspond to those of the cash-receipt column.

Form 14.—CASH RECEIPTS,

	1	2	3	4	5	6	7	8	9		
Date, 1915.	Item.	Rec. No.	Net cash.	Returns and allowances.	Coupons re- deemed.	Coupons issued.	Merchan- dise sales.	Accounts receivable.	Bills receivable.	Bills payable.	Interest.
Jan. 1	Cash on hand		100								
	Cash in Bank		2,480								
1	As per Summary	376	435 80		38	45	179	21 80	100		2
2		377	829 50	1 50	50	40	190	26		500	
	Total for Month		9,589 90	2 10	1,580	1,060	2,900	2,800	350	900	12

Left side.

FARMERS' COOPERATIVE ASSOCIATION.

10	11	12	13	14	15	16	17	18	Unclassified.		
Capital stock.	Stock notes.								Amount.	L. F.	Account credited.
.....	.....	.....	.....	.....	.....	.....	.....	.....	100	.....	.....
.....	.....	.....	.....	.....	.....	.....	.....	.....	2,480	.....	.....
.....	.....	.....	.....	.....	.....	.....	.....	.....	125 50	10	Furn. & Fix.
50	75	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
175	275	.....	.....	.....	.....	.....	.....	.....	2,710	.....	.....

Right side.

NOTE.—By omitting columns 13 to 18 and making the heading of column 12 read "Unclassified," this form may be reduced to one sheet or page.

Form 15.—VOUCHER CHECK.

STATEMENT.				Dr.
To <i>M. Field & Co.</i>				
Date.	Invoice.	No.	Amount.	
<i>Dec. 25</i>		<i>3682</i>	<i>35—</i>	
<i>Total</i>				
DEDUCTIONS.				
	<i>Disc. 2%</i>		<i>70</i>	
<i>Ntd</i>			<i>\$</i>	<i>34.30</i>

Do not cut apart.

No. 478

FARMERS' COOPERATIVE ASSOCIATION.

GENERAL MERCHANDISE.

\$34.30

Pay to the order of *M. Field & Co.*

Thirty-four and 30/100

[Place] *Jan. 2, 1915*

Dollars

FIRST NATIONAL BANK

[Place]

FARMERS' COOPERATIVE ASSOCIATION,

By *J. B. Doe,*
Mngr.

Form 16.—REMITTANCE BLANK.

FARMERS' COOPERATIVE ASSOCIATION

[Place] Aug. 14, 1915.

M. Field & Co.,
Omaha.

GENTLEMEN:

Enclosed please find our check No. 642 in payment of invoices as follows:

Date of Inv.		No.	Deductions.			Face.		Net.	
Aug.	5	M638	Short.....	40					
			Disc. 2%.....	1—		50	40	49	
	8	6392	Disc. 1%.....	75		75		74	25
Net remittance								123	25

Yours truly,
FARMERS' COOP. ASSN.,
By J. B. Doe,
Mngr.

Prepare in duplicate if voucher check is not used.

Form 17.—CASH PAYMENTS,

1 2 3 4 5 6 7 8 9

Date, 1915.	Name.	Check No.	Net cash.	Merchan- dise dis- count.	Coupons issued.	Merchan- dise pur- chased.	Produce pur- chased.	Returns and al- lowances.	Freight and express.	Salaries and labor.	Advertis- ing and delivery.
Jan. 2	Marshall F. & Co.	478	24.50	70		35					
	A. Rich	9	70								
4	Produce bought				24		24				
	City Book Store	80	7								
	First National Bank	1	10								
	Total for month		7,252.60	65	630	4,900	630	470	8	360	22

Left side.

NOTE.—Form 17 is designed for a strictly cash business, where all the bills are discounted. If a credit business is done with dealers a column must be devoted to Accounts Payable. See pages 29 and 48.

Form 18.—CASH SUMMARY—RECEIPTS, 1915,

1 2 3 4 5 6 7 8 9

Date.	Item.	Rec. No.	Net cash.	Returns and allow- ances.	Coupons redeemed	Coupons issued.	Merchan- dise sales.	Accounts receivable.	Bills receiv- able.	Bills payable.	Interest.
.....	January .....	.....	9,589 90	2 10	1,580	1,050	2,900	2,800	350	900	12
.....	February .....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
.....	March .....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
.....	December .....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
.....	Total for year .....	.....	89,208	30	19,600	12,390	34,900	35,475	4,560	13,000	180

Left side.

FARMERS' COOPERATIVE ASSOCIATION.

10	11	12	13	14	15	16	17	18	Unclassified.		
Capital stock.	Stock notes receivable.								Amount.	L. F.	Accounts credited.
									2,710		Segregation:
175	275										Bal. Ford. 2,580.00
											Furn. & Fix. 125.00
											Commission 178.00
											Total 2,883.00
2,050	3,400								2,883		

Right side.

Totals journalized; page 33.
NOTE: Payments summary is similar to Form 17.
See note, page 19.

OPERATING RECORDS.

A.—STRICTLY CASH BUSINESS.

The operating records of a store doing an exclusive cash business are extremely simple, consisting of but three books—the cashbook, the journal, and the ledger. In fact, the cashbook alone is in current use, since only the totals from the cashbook are journalized and posted into the ledger at regular intervals—monthly, quarterly, semiannually, or only annually, as may be desirable in different stores.

CASH RECEIPTS.

In a cash business the original entry of receipts is made in the cash register, or on counterfoil sales books passed to a cashier, if an overhead carrier system is used. The cash register is usually provided with a convenient form for analyzing and proving the daily cash receipts, but this should be used only as a memorandum of original entry, and should not displace any of the records suggested. The Daily Summary of Receipts (Form 13), page 18, may be used if the stock form is not adopted. It should have the same general titles as the cash receipts book, and should constitute the original for the daily entry in the cash receipts book.

USE OF THE CASH REGISTER.

In a moderate-sized business it is recommended that a good type of register with departmental keys adapted to the nature of the business and a grand total for the use of the auditor be used. The register should furnish a ticket for every sale. On one side should be printed the card of the store and some attractive advertisement or statement; on the other side, the sales number, date, and amount (Form 10).

CASH REGISTER TICKET.

Dividends are based exclusively on the cash register tickets, but care must be exercised that the customers understand definitely the method of handling them. Either they must be given definite instructions that they are to return the tickets, properly listed on an envelope at the end of each month or other regular period, and that no dividends are allowed unless the tickets are returned within the time specified; or the store must provide some regular method of taking care of the tickets. The latter plan is often more satisfactory, because many customers object to being required to take care of the tickets. If the store keeps the tickets, great care must be exercised that the name appears on every ticket, and that the customer drops them in a suitable receptacle; for instance, one resembling a ballot box. At stated intervals the tickets are taken out of

the box and are sorted under the different customers' names. This latter method is more satisfactory from the customer's point of view, but it throws great responsibility on the store and often leads to disagreements as to the credit to which the customer is entitled. Whether one form or the other is used, the tickets should be listed on the face of an envelope, as shown in Form 11, and properly filed until the dividend is declared.

BANK DEPOSITS.

A fixed amount—say \$100—should be set aside for change and for petty expenses, after which all receipts should be deposited. It will be found a good practice and of great convenience to the auditor if the exact amount of each day's receipts is deposited. If deposits are not made daily, the exact amount of the last two or three days should be deposited. If the receipts of a certain day are \$210.40, the deposit should be exactly that amount, and not, for example, \$200. The duplicating deposit tickets should be used, so that a record is kept of every deposit.

CASHBOOK.

The Cashbook is divided into two parts—the record of cash receipts and of cash payments. Because the entries of cash payments are greatly in excess of the items of receipts, and because the classification titles of payments are much more numerous than those of the receipts, it is recommended that the latter be kept in one book and the payments in another. Or if a loose-leaf book is used, the receipts sheets may be placed in front of the book and the payments in the back part. A convenient number of special columns in each section are recommended. Many arguments may be cited in favor of the special-column cashbook, chief of which are: Ready reference, facility of proving the results, and economy of time in keeping the books. Six, 12, 18, and 24 column books are on the market at very low cost.

EXPLANATION OF THE COLUMN CAPTIONS.

The numbers in parentheses correspond to the numbers of the general accounts, pages 36 to 39. It will be noted that this form of cashbook contains the special balancing features; columns 1, 2, and 3 being the debit columns, and 4 to 18 the credit columns. All entries in the Cash Receipts Book (Form 14) are made from the Daily Summary of Receipts (Form 13); hence, no details are entered in this book.

1. *Total*.—This column contains the net cash received, including the balance at the beginning of the period. (1) and (2)

2. *Returns and allowances*.—This column is used only when a credit business is done. It contains discounts and deductions on accounts and bills receivable. (25)

3. *Coupons redeemed*.—This column is used only in case the coupon system is used, in which case the coupons received during the day are entered in this column through the Daily Summary. (16)

4. *Coupons issued*.—In this column are entered amounts received for coupons sold, cash being debited and coupons credited. Until they are paid they stand as a liability. (16)

5. *Cash sales*.—Receipts for sale of merchandise and produce are entered in this column. (24)

6. *Accounts receivable*.—Used only in a credit business. In it are entered only amounts to be credited to the customers' accounts. It is the controlling account of the credit side of the Customers' Ledger or Account File. (3)

7. *Bills receivable*.—Used only in a credit business. In it are entered only receipts from signed obligations due the business. Great care should be taken not to confuse columns 6 and 7. (5)

8. *Bills payable*.—In this column are entered all amounts borrowed from the bank or other parties. The difference between this column and column 16 in the Cash Payments must at all times represent the amount of bills outstanding against the business. (14)

9. *Interest received*.—In this column are entered amounts of interest received on stock notes and bills receivable. This column is used only where a credit business is done, or where the stock is not fully paid up. (39)

10. *Capital stock*.—Receipts for capital stock which have not been entered previously as Stock Notes Receivable. In the latter case, the entry is made in number 11. (17)

11. *Stock notes receivable*.—In this column are entered amounts received on stock notes as explained under (6).

12. *Unclassified*.—Amounts which can not be classified properly under any of the other headings. The title of the accounts should be written clearly in the space provided, and each entry must be posted to the proper account in the General Ledger when the summary is made at the end of the year. These are the only items which are so posted, since the totals of the other columns are carried forward to the Summary, and from there posted once a year to the General Ledger.

CASH PAYMENTS.

All payments, except petty items, are made by check on properly approved vouchers. A part of the change fund referred to on page 27 should be handed to the cashier or bookkeeper for petty expenses, freight, and the like, and at stated intervals the items should be billed, properly classified, approved, and a check drawn for the bill in favor of the bookkeeper or cashier. This obviates the necessity of entering a large number of petty items in the general cashbook,

and it gives to the manager an opportunity to approve the petty expense bills before they are entered.¹

ORDERS AND REMITTANCES.

Since no ledger accounts are kept with the creditors, it is important to adopt a system of orders and remittances which insures a complete record and enables the creditor to balance his account readily. Every order for merchandise should be reduced to writing. Aside from its value to the office it is practically impossible for the auditor to verify the amount due creditors without this record. Salesmen should be required to use the regular form, and if orders are placed orally or by wire in every case they should be confirmed in writing. Form 25 will be found convenient. *When the invoice is checked it should be entered in the Invoice Register (Form 26).* The most satisfactory voucher is a check with the remittance form attached (Form 15). These checks should be made in duplicate, the carbon copy being retained as the original entry of the payment. Both the original and the duplicate should be numbered consecutively, and the latter should be filed with the invoice or voucher. Then the vouchers should be placed in consecutive order on an arch file until audited. Should it be desired to use the nonduplicating checks, usually furnished by the bank, the remittance notice may be used separately, but the duplicate should be handled in the same manner as above indicated.

So far as practicable, part payment of bills should be avoided. Checking accounts and filing will be facilitated if the exact amount of bills and any reduction or adjustment is noted on the Remittance Blank (Form 16).

CASH PAYMENT BOOK.

Like the Cash Receipts Book, the Payments Book is only a tabulation of the vouchers, since no payment is made without a proper voucher. The date, payee, number, total, and distribution are entered, each payment requiring but one line. The form is shown on pages 22-23.

EXPLANATION OF COLUMN CAPTIONS.

1. *Total*.—Contains all the net cash amounts paid. Corresponds to the face of the checks issued. (11 and 12)

2. *Merchandise discount*.—In this column are entered all amounts deducted from the face of the bills in consideration of payments before the bills are due. (38)

3. *Coupons issued*.—In this column is entered the amount of coupons issued for produce. The total is posted at the end of the

¹ For a further explanation of petty cash see Bulletin 178, U. S. Dept. of Agr., Cooperative Organization Business Methods.

year to the credit of coupons and remains a liability until redeemed. (16)

4. *Merchandise purchases*.—The total amount of the invoices of payments for merchandise. (28)

5. *Produce purchased*.—The total value of the produce paid for in coupons or cash. It is important that all the produce purchased for coupons or cash be entered in this column, so that reliable statistics may be had on this branch of the business. In a credit business it is sometimes found convenient to credit the customer's account with the produce bought. In that case a special produce register is kept, upon which are recorded all items of produce for merchandise without the use of coupons. However, all such exchanges should be properly recorded on the produce register, so that a complete account is kept of all produce purchased. (29)

6. *Returns and allowances*.—In this are entered cash refunds for goods returned by customers. (25)

7. *Freight, express, and cartage*.—In this are entered all payments for transportation on inward goods. (31)

8. *Salaries and labor*.—All salaries and wages are entered in this column. Later they are subdivided under accounts. (41) and (45)

9. *Advertising and delivery*. (42) and (43)

10. *Miscellaneous buying and selling expense*. (44)

11. *Office expense*. (46)

12. *Rent, insurance, and taxes*. (48)

13. *Light, heat, water, power*. (49)

14. *Interest*. (53)

15. *Telephone and telegraph*. (52)

16. *Bills payable*. (14)

17. *Furniture and fixtures*.—In this column are entered all payments for additions to furniture and fixtures, but must not contain anything for merchandise or renewals and repairs. (10)

18. *Unclassified*.—In this column are entered all items which can not properly be included under any of the preceding headings. The account titles are indicated in the space provided, and each item is posted to the proper account in the General Ledger as explained on page 36.

BALANCING THE CASHBOOK.

As already stated, the sum of columns 1, 2, and 3 equals the sum of the totals in the distribution columns. This must be proved before any totals are forwarded from page to page. The cash balance should be noted in the Receipts Book "items" column from time to time. (See Form 14.) But this is only a memorandum. The totals should be carried forward until the end of each month, when the totals are entered in the Summary (Form 18).

RECONCILING THE BANK ACCOUNT.

Usually the bank returns the canceled checks at the end of each month with a statement of the balance. It should be the first duty of the bookkeeper to arrange the checks numerically and reconcile the bank balance with that shown by the cashbook. This is done by the following formula:

Store balance.....	\$742.37
Add outstanding checks.....	65.40
Bank balance.....	<u>807.77</u>

CASH SUMMARY.

The cash summary is merely a recapitulation of the totals of the receipts and payments. The same form is used and no change whatever is made in the classification. The cash statement (Form 7) is the total of this summary (Form 18).

COUPON AND SCRIP SYSTEM.

One of the most serious objections to strictly cash business is the inconvenience to the customer in handling change. The percentage of customers who carry a bank account and prefer to pay monthly by check is growing year by year. The convenience of ordering by telephone and having goods delivered in the absence of the housekeeper is recognized by all. To overcome these objections coupons are often sold in convenient books of \$5, \$10, or \$25. Many stores find this system so valuable that they offer a small discount for such advances. So long as the store has no surplus capital, such discount should be more than offset by the trade discount obtained from dealers for prompt payment. As the coupons are sold for cash only, the sale is entered from the Daily Summary into the Receipts Book. The total coupons sold, less the coupons returned, represents a liability, and must be so entered in the Balance Sheet (16). It is not necessary to provide the cash register with a separate key for the coupons, because they should be counted in as cash in the daily balance. Every coupon book should be numbered and a proper receipt should be taken for every book issued. The books should be issued in numerical sequence, and the auditor should require a strict accounting of the books on hand at each audit. A typical book has the following instructions on the cover:

1. Under no circumstances will these coupons be received in payment for goods purchased prior to the sale of this book.
2. The unused portion of this book may be redeemed at the face value of the returned coupons, less 3 per cent, provided the book is presented within one year from date of sale indicated by punch mark in margin of cover.
3. Detached coupons will not be redeemed nor accepted in payment for merchandise. When the coupons have been exhausted, **PRESERVE THIS COVER** as a receipt for

money paid by you to the store, and when a dividend is announced YOU WILL RECEIVE REBATE based upon the amount paid for this book.

4. If this book is lost or stolen, report the fact at once, giving the number of the book. It is not transferable and will not be honored if presented by another than yourself or one authorized by you. These conditions are necessary in order to protect the purchaser.

I agree to the above conditions:

....., Purchaser.

Date of sale, 19..

Many of the most successful stores use scrip or metallic tickets, preferably aluminum, for the payment of produce. The tickets are made in the same denominations as coins, except that the penny is seldom used. This seems to be a good practice for stores which do only a limited buying of produce and where there is no good reason for paying cash. Where large purchases are made of eggs, butter, wool, and the like, and it becomes necessary to pay cash, a check should be drawn in the usual manner. Coupons paid for produce must be counted as a liability until redeemed. It is entered on the Daily Summary and in the Cash Payments as shown in Forms 17 and 18.

Form 19.—JOURNAL.

SAMPLE ENTRIES.

June 15, 1915.

L. F.		Dr.	Cr.
	Pursuant to Articles of Association and Minutes of June 1st, and 8th, the Farmers' Cooperative Association began business with the following resources and liabilities:		
C. B.	Cash	2,500 00	
7	Stock Notes	3,500 00	
1	Capital Stock		6,000 00
	Being 60% of the authorized capital stock, as per stock subscription agreements 1-145		
	<i>January 31, 1915.</i>		<i>Page 26</i>
4	Accounts Receivable	2,600 00	
3	Merchandise Sales		2,600 00
	Credit sales for January. For details see J. 30.		
	<i>January 31, 1915.</i>		
3	Merchandise Sales	6 00	
4	Accounts Receivable		6 00
	Returns and Allowances for January. For details, see J. 40.		
	<i>December 31, 1915.</i>		
2	Cash	86,628 00	
3	Merchandise Sales	30 00	
6	Coupons (Redeemed)	19,600 00	
6	Coupons (Issued)		12,390 00
3	Merchandise Sales		34,900 00
4	Accounts Receivable		35,475 00
5	Bills Receivable		4,560 00
8	Bills Payable		13,000 00
9	Interest		180 00
1	Capital Stock		2,050 00
7	Stock Notes		3,400 00
10	Furniture & Fixtures		125 00
11	Commission		178 00
	Cash Receipts for the year, as per Summary C. B. 16.		
	Posting authorized, J. B. Doe, Manager.		

JOURNAL.

The use of the Journal is very restricted in modern bookkeeping. It is confined practically to four classes of entries—opening entries, correction or adjusting entries, periodical summary entries, and closing entries. These several entries are made in the Journal, with suitable explanations, with a view to finally posting them into the General Ledger. An illustration of opening entries is the first above.

The advantages of first journalizing the items to be posted are (1) that the entries may be checked and approved by the proper authority before posting; (2) it facilitates the preparation of the trial balance and statement, and (3) it is a very great assistance to the auditor. The trial balances and statements should also be copied in the Journal. Form 19 illustrates the use of the Journal.

During the progress of the business, certain adjustments and corrections must be made which can not properly be made through the Cashbook. Such entries are made in the Journal. For example, if it is found advisable to exchange a surplus of coal which previously was charged to expense, an entry is made in the Journal with suitable explanations and detail. A temporary settlement for a bill of merchandise by a customer may be made by a note. At the end of the year the totals for the different columns in the Cash Receipts Summary are journalized, the items in the "unclassified" column being segregated and posted to the proper accounts. A similar entry is made for the cash payments.

At the end of the year, in order to find the progress of the business, the books are closed. According to the Manager's Report (Form 7), the inventory of merchandise is \$14,900; accrued interest on bills receivable, \$31; office supplies, \$20; and two liability inventories—accounts payable, \$1,600, and accrued interest on bills payable, \$21. The proper entries are made in the Journal and posted as follows:

Inventory.....	\$14,951.00	
Merchandise.....		\$14,900.00
Interest.....		31.00
Expense.....		20.00
Merchandise.....	1,600.00	
Interest.....	21.00	
Inventory.....		1,621.00

In order to find the profit on Trading, this account is opened and charged with the different items of cost and credited with the sales. The charges and credits are identical with the items in Form 7, II A. In fact, the Trading Account contains the same facts as the statement, but in ledger form.

Journal entries are then made to transfer the Net Profit from the Trading Account and the different profit and loss accounts to the Profit and Loss account. This is identical in content with Form 7, II B.

A Balance Sheet is now taken from the ledger, which is practically identical with Part I of the Manager's Report.

In order to open the books for the next year's business, the net profit is transferred to the Surplus account by means of a journal entry. The Inventory account is closed by a journal entry, which is the reverse of the closing inventory entry above.

Form 20.—GENERAL LEDGER.

CAPITAL STOCK.

(1)

1915					1915				
Dec.	31	Balance		15,350 00	Jan.	1	Balance		9,950 00
					Dec.	31	Cash	26	2,050 00
						31	Stock Notes	27	3,350 00
					1916				
					Jan.	1	Balance		15,350 00

CASH.

(2)

1915					1915				
Jan.	1	Balance		2,580 00	Dec.	31	Payments	27	85,818 00
Dec.	31	Receipts	26	86,628 00		31	Balance		3,390 00
1916									
Jan.	1	Balance		3,390 00					

MERCHANDISE SALES.

(3)

1915					1915				
Jan.	31	Ret. & Allow.	26	6 00	Jan.	31	Sold on acc.	26	2,600 00
Dec.	31	" "	26	30 00	Dec.	31	Cash Sales	26	34,900 00
	31	" "	27	90 00	Feb.	to	Dec. Sold on acc.	27	38,630 00
Feb.	to	Dec. Ret. & Allow.	27	74 00					
Dec.	31	To Trading Acc.	27	75,930 00					

ACCOUNTS RECEIVABLE.

(4)

1915					1915				
Jan.	1	Balance		6,885 00	Jan.	31	Ret. & Allow.	26	6 00
	31	Sold on acc.	26	2,600 00	Dec.	31	Cash	26	35,475 00
Feb.	to	Dec. Sold on acc.	27	38,630 00	Feb.	to	Dec. Ret. & Allow.	27	74 00
					Jan.	to	Dec. Bills Rec.	27	5,060 00
					Dec.	31	Balance		7,500 00
1916									
Jan.	1	Balance		7,500 00					

BILLS RECEIVABLE.

(5)

1915					1915				
Jan.	1	Balance		1,800 00	Dec.	31	Cash	26	4,560 00
Jan.	to	Dec. on acc.	27	5,060 00		31	Balance		2,300 00
1916									
Jan.	1	Balance		2,300 00					

Form 20.—GENERAL LEDGER—Continued.

COUPONS.

(6)

1915					1915				
Dec.	31	Redeemed	26	19,600 00	Jan.	1	Balance		100 00
	31	Balance		150 00	Dec.	31	Issued	26	12,390 00
						31	"	27	7,200 00
					1916				
					Jan.	1	Balance		150 00

GENERAL LEDGER.

The General Ledger contains the accounts of the business as a whole. It contains in summarized form the accounts showing the resources, liabilities, losses and gains, and the administrative accounts. In a corporation all the general ledger accounts are impersonal, even when a credit business is done either with creditors or customers, or both. A convenient type of ledger is shown in Form 20.

It is very desirable from every standpoint that the accounts of similar businesses be standardized so that one business may profit by the experience of the rest. The Harvard Classification¹ of retail accounts has therefore been adopted to a considerable extent as the ledger accounts. They are equally adapted to large or small businesses. The titles and their explanation are as follows:

EXPLANATION OF THE GENERAL ACCOUNTS.

There are only two classes of accounts in the General Ledger, namely, accounts with property and nominal accounts. The accounts with property represent, not only accounts with physical property, but also property belonging to the business in other people's possession, such as accounts receivable, commission due, interest, and so on. The nominal accounts are those showing losses or gains, or the results of the business, such as interest, taxes, insurance, salaries, general expenses, etc. In so far as property accounts show appreciation or depreciation, and also if the property has been sold for more than its cost, such accounts represent also losses or gains. This is true of merchandise accounts, real estate, and furniture and fixtures.

The titles of the accounts and their contents are as follows:

1 and 2.² *Cash*.—This balance includes (1) the amount set aside for a revolving fund and for petty expenses, as explained on page 29, and (2) the balance due from the bank or banks. This part of the cash account should agree exactly with the bank statement, due regard being taken for the outstanding checks.

¹ Harvard University—Bureau of Business Research. Bulletin No. 3. Harvard System of Accounts for Retail Grocers. 1914.

² The numbers correspond to the items in the Manager's Report, Form 7.

3. *Accounts receivable*.—This account is used as a controlling account if a credit business is done. It shows a debit balance, if any, which equals the amounts due from customers as shown under the several accounts in the customers' ledger, or in the account file. It should be watched very closely, and under no circumstances should the manager allow any deviation from an exact balance between that account and the special accounts in the file.

4. *Reserve for bad debts*.—A close check should be had upon the losses due to credit, and a definite rate established. When this is found, the amount should be deducted from the net profit, and credited to this account. Should this rate be found to be too large, the rate should be decreased; if too small, the rate should be increased from time to time. Credits to this account are offset by corresponding debits to the Loss and Gain account. Sometimes it is well to charge the entire balance of any account to Loss and Gain, and then if an amount is collected enter it as a gain.

5. *Bills receivable*.—This account shows a debit balance, if any, and represents signed obligations due the business, including notes, mortgages, drafts, and other negotiable papers. This account is used only where a credit business is done.

6. *Stock notes receivable*.—This account shows a debit balance, if any, and represents the amount of stock notes due the business. The balance should be kept as low as possible, and care be taken to collect interest on every note.

10. *Furniture and fixtures*.—This account represents the inventory value of the furniture and fixtures at the beginning of the period, together with all additions, but not renewals and repairs. Nothing intended for sale should be included in this account.

14. *Bills payable*.—This account shows a credit balance, representing the amount of signed obligations due others at the end of the period.

16. *Coupons outstanding*.—This account shows a credit balance and represents the amount of coupons outstanding, or the difference between the amount sold and redeemed. Only one entry a year need be made in this account, at the end of the period.

17. *Capital stock*.—This account shows a credit balance, and represents the amount of stock outstanding. It is the controlling account of the Membership Ledger, and the balance must equal the amount of cash received for stock and stock notes, together with the stock notes on hand.

18. *Surplus*.—This account shows a credit balance and represents the undivided profits of a concern. The net gain at the end of the year is entered in this account.

21. *Dividends paid*.—When trade dividends are declared by the directors a journal entry is made, debiting Surplus, and crediting

Dividends Declared. When the latter are paid, Dividends Declared are debited, and Cash credited, through the Cash Payment Book (18). This account should balance at the end of the year, since no unpaid dividends should be reported.

24. *Gross sales.*—This account represents the gross sales of merchandise, and contains only credit items. At the end of the period this amount is credited to the trading account, which contains exactly the same items, in account form, as the Trading Statement.

25. *Returns and allowances on sales.*—This account represents the returned goods and allowances on merchandise sold. It may be kept also on the debit side of the Sales account. If a separate account is kept, it will contain only debit entries until the end of the year.

28. *Merchandise purchases.*—This account is charged with all cash purchases of both merchandise and produce, as shown in columns 4 and 5 of the Cash Payments, which should be entered only once a year. At the end of the year the unpaid bills are also charged to this account. Merchandise returned may be entered either under a separate heading, or it may be entered on the credit side of Merchandise Purchases Account.

30. *Accounts payable.*—This account is not used at all unless regular creditors' accounts are kept as stated on page 48. In that case, only one entry need be made at the end of the year, showing the unpaid bills. This balance should be checked with the creditors' statements. (See Auditing, p. 50.)

31. *Freight, express, and cartage.*—All charges for freight, express, and cartage on incoming goods intended for sale are entered in this account. At the end of the period they are charged to the Trading Account.

35. *Turnover, or net cost of merchandise sold.*—This is defined as the prime cost of sales. It may be estimated at any time by subtracting the given percentage of gross profit from the gross sales. Thus, if the sales are \$12,000 and the average rate of gross profits is 20 per cent, the turnover is \$12,000 less \$2,400, or \$9,600.

38. *Merchandise discount.*—The discounts taken on merchandise are accumulated in column 2 in the Cash Payments, and are entered in this account only once a year. It represents a credit balance.

39. *Interest.*—This account shows a debit or credit balance, according as more interest has been received or paid, and it shows the amount of interest received on notes due the business and interest paid on notes due others. Only one entry for the period is made for the year on each side of this account, being the totals of column 9 in the Cash Receipts and column 14 in the Cash Payments.

41. *Salaries and labor.*—The salaries and wages are entered in column 8 in the Cash Payments Book as payments are made, and the

total is entered on the debit side, at the end of the year, as explained on page 30.

42. *Advertising*.—This is treated the same as 41.

43. *Delivery*.—Same as 41.

44. *Miscellaneous buying and selling expense*.—This account contains such items as order and requisition blanks, sales books, twine, wrapping paper, containers, and the like.

45. *Management and office salaries*.—These salaries are a part of the total of column 8 in the Cash Payments. The manager's salary in proportion to the time spent in management; the salaries of the bookkeeper, auditors and secretary, and directors' fees are included.

46. *Office expense*.—This item includes office books and stationery, stamps, ink, pencils, and other office supplies, but not permanent fixtures, such as office desks, typewriters, and adding machines; in short, anything which is consumable and which is used in the office. Sales books, however, should be charged to the selling expense, order and requisition blanks to purchasing expense, etc.

48. *Rent, insurance, and taxes*.—The contents of this account are self-explanatory. In the statement it should be subdivided under the three headings.

49. *Light, heat, water, and power*.—These titles are all self-explanatory. The charges are collected in one column in the Cash-book and later subdivided.

50. *Depreciation on furniture and fixtures*.—Rates of depreciation should be established, and a Reserve for Depreciation of Furniture and Fixtures set up and accumulated every year, to make up for the loss to this property in the same manner as No. (4).

51. *Repairs*.—This account contains charges for expenditures for the general upkeep of the property, such as painting, repairs to fixtures, and glazing. It is accumulated in column 18 of Cash Payments during the year, and from there entered in the General Ledger at the end of the year.

52. *Telephone and telegraph*.—The contents of this account are self-explanatory.

The trading account.—This is a summary of accounts and items 24 to 36, inserted in the Ledger as a permanent record of the Trading Statement. It corresponds exactly to the statement, except that it is in the form of a ledger account.

Stock turns.—This is the approximate number of times the stock is sold, and is found by dividing the turnover (35) by the average inventory (27 and 33). Thus, if the turnover is \$30,000 and the inventories are \$8,000 and \$4,000 at the beginning and end of the year, respectively, the number of stock turns is 5.

Form 21.—CONTINUOUS TRIAL BALANCE, 1915.

Account.	Acc. No.	October.		November.		December.	
		Dr.	Cr.	Dr.	Cr.	Dr.	Cr.
Capital Stock....	1	-----	15,010	-----	15,225	-----	15,350
Cash.....	2	70,360 80	69,260 40	80,369 25	72,394 20	89,208	85,818
Totals		120,623 15	120,623 15	131,240 60	131,240 60	142,180 20	142,180 20

TRIAL BALANCE.

As is evident from an examination of Form 19, debits are equal to the credits, hence a balance should exist between the two sides of the Ledger when the posting is completed. (See Form 21.) This may be taken monthly, or as often as desired. Since there are only a few fixed accounts, this should be a very easy matter if the work is done correctly. It is suggested that the totals of each side of the account be used rather than the balances, since experience has proved that this method obviates many chances for mistakes. The Trial Balance of the totals is also a convenient summary of the business for the year.

CLOSING THE LEDGER.

The expression "closing the ledger" is used because of time-honored custom, though it is really a misnomer. The process consists merely of transferring the balances of accounts showing losses or gains to a summary Loss and Gain account which will then show either a net gain or loss. The net gain is reported to the board of directors, which orders its distribution into Dividend, Reserves, Surplus, etc. The loss and gain accounts will then balance, and only resources and liabilities will be shown in the ledger, including, of course, the liabilities to the stockholders; that is, Capital Stock, Dividends, Reserves, and Surplus. In other words, each fiscal period will start without any open loss and gain accounts, which have served their purpose at the end of each period in showing the sources of profits or losses. It is assumed that the bookkeeper is familiar with the method of closing the ledger.

Before the ledger can be closed, however, certain adjustments must be made in the loss and gain accounts. Accounts representing property must be credited with the value of the stock in hand, and accounts showing rates and allowances must be adjusted for unsettled claims. All such lists of property or claims are called inventories. The customary loose method of making these adjustments in red ink directly into the ledger is not recommended. *Every change of whatever nature in the general ledger should first be entered in the*

journal *with suitable explanations*, and *should be approved by the manager before they are posted*. (See page 33.) In this way the auditor will know at a glance just what has been entered in the ledger, and the taking of a trial balance will be greatly facilitated.

B.—BOTH CASH AND CREDIT BUSINESS.

A system of accounts which contains a complete analysis of a cash business is given in the preceding pages. But, unfortunately, few stores are able to confine themselves to this simple method of doing business. It is therefore necessary to outline the additional records required where credit is extended to customers, and where it is impracticable to discount all bills. It should be emphasized that all the preceding records are necessary and that the following are merely *additional credit records*. They are (1) accounts with customers, kept either (*a*) in a separate ledger or (*b*) in an account file; and (2) accounts with creditors, kept likewise in a separate ledger or file. Four additional accounts are kept in the general ledger, viz: A controlling, or summary, account of Accounts Receivable; and another with Accounts Payable; sometimes settlements will be made temporarily by notes, and occasionally money will be borrowed. Hence accounts with Bills Receivable and Bills Payable must be kept. The method of keeping these accounts will be discussed in the above order.

Form 22.—SALES SLIP.

Acct. No. 32			
FARMERS' COOPERATIVE ASSOCIATION.			
[Place] Jan. 15, 1915.			
E. K. Jones.			
Dept. K.	Sold by J. G.	Checked by F. W.	Got by Jannen.
	Items.		Totals.
	Amount forward.....		1 26 40
1	Sugar	1	
2	1 Box Apples.....	1 50	
3	Olives	25	
4	Salt	10	2 85
5	.....		1 29 25
6	.....		
7	.....		
8	.....		
9	.....		
10	.....		
11	.....		
12	.....		
13	.....		
14	.....		
15	.....		

¹ This amount is not forwarded unless a slip file is used.
Written in in triplicate.

Form 24¹.—BILLS RECEIVABLE REGISTER.[illegible]

1 Bills Payable Register and Stock Notes Register are of the same form as 24.

Form 25.—ORDER FOR MERCHANDISE.

FARMERS' COOPERATIVE ASSOCIATION.				
Order No. 52.			[Place], January 2, 1915.	
M Wholesale Grocery Co., Chicago, Illinois.				
Please enter our order for the following goods to be shipped via C. P. R. Q. Ry. Terms: 2/10; n/30.				
	Lot.	Quantity.	Description.	Price.
1	Xj	4	cases XXX Pork & Beans.....	90
2	-----	5	cases Sugar Corn.....	92
20	-----	-----	-----	-----
Note: Please send invoice and bill of lading promptly. Use our order number in billing, correspondence, etc.			Please send invoice and bill of lading promptly. Yours, truly, FARMERS' COOPERATIVE ASSOCIATION, By J. B. Doe, Mgr.	

In duplicate or triplicate.

Form 26.—INVOICE REGISTER,

Date 1916.	Firm.	Address.	Amount.	Merchandise returned.	-Short. +Over.
Jan. 5	Wholesale Grocery Co.....	Chicago	72 40		
10	Field & Co.	Chicago	246 80	8	+50
15	General Hardware Co.....	St. Louis	62 40		

Left side.

FARMERS' COOPERATIVE ASSOCIATION.

Discount.			Freight and drayage.	Net due.	Due date.												Date paid.	Remarks.	
Rate.	Days.	Amount.			1	2	3	4	5	6	7	8	9	10	11	12			Yr.
1	10	72	240	71 68	15											15	Jan.	14	
3	10	7 15	720	231 15	20													19	See letter Jan. 2.
2	30	1 05	175	61 05		14												Feb.	12

Right side.

ACCOUNTS RECEIVABLE.

The original entries of all time sales are made by the salesmen on triplicating sales slips (Form 22). One copy is given to the customer, and two are retained by the salesman, and rung up on the cash register under Credit Sales. The time sales are carefully listed and checked by each salesman at the end of the day, each ticket being accounted for. When thus checked and proved, they are handed to the bookkeeper, who arranges the slips in alphabetical order, binds each day's slips together, and lists them, preferably on an adding machine. The daily total is entered on a special page in the journal under the general heading—

CREDIT SALES FOR JUNE, 1915.

June 1.....	\$126. 40
2.....	92. 80
* * * * * *	
Total.....	<u>2, 600. 00</u>

At the end of the month a journal entry is made for the total of the month's sales.

The individual charges are posted daily as debits under the individual accounts in the Customers' Ledger (Form 23). The duplicating statement ledger is used, and entries are made with a sharp indelible pencil over a pencil carbon. The original of the ledger account is sent to the customer as a statement at the end of each month, or as often as desired, the duplicate being retained as the permanent record.

BILLS RECEIVABLE.

Occasionally, in a credit business, accounts are settled temporarily by note, time draft, or other signed obligation. Such papers are listed on Form 24, and at the end of the month a journal entry is made and posted into the General Ledger as follows:

Bills receivable.....	\$500. 00
Accounts receivable.....	\$500. 00

The individual notes are credited to the several accounts in the Customers' Ledger.

GOODS RETURNED.

Goods returned are entered on a credit memorandum, which is printed on a slip the same size as the sales ticket, but usually in red. The best practice is to use but one book of credit memoranda, to be kept in the office; but if the memorandum is written by the salesperson the slips must be rung up on the cash register in the same manner as the sales slips, except that instead of being a Credit Sale it would be entered as a Returned Sale. The goods returned memoranda are then listed on a separate page under an appropriate heading the same as the sales, and at the end of the month posted through the Journal.

PRODUCE.

Most cooperative stores buy produce in limited quantities from farmers. It is almost the unanimous opinion of retail stores that produce is unprofitable. For this reason, and for statistical purposes, a separate account should be kept of this branch of the business. The original entry may be made either on the regular credit memorandum, or, preferably, on a special slip for this purpose. These slips may be totaled at any time to ascertain the volume of produce bought. If the produce is left by the customer for credit, all the credit slips must be posted to the respective accounts, and the total produce entered in the Journal in the same manner as sales.

If the produce business is very large, a special book may be used as a Produce Register, having the same form as the Journal. Coupons may be used to advantage in handling produce, as explained under Cash Payments.

ACCOUNTS PAYABLE.

Accounts Payable are amounts due others from the association. If possible such accounts should be avoided entirely and every bill discounted, in which case no creditor's ledger is required, the orders and remittances being handled as illustrated on page 29. Where accounts payable records are kept, the original entry is the creditor's invoice. As the invoices come in they are checked, entered in the Invoice Register (Form 26), and filed in the tickler numbered 1 to 31, corresponding to the days of the month. An account is kept with each creditor in a special ledger, the items being posted to the credit of the respective accounts from the Invoice Register. At the end of the month or as often as desired the register is totaled and the amount entered in the Journal as follows:

Merchandise.....	\$2, 000. 00
Accounts Payable.....	\$2, 000. 00

Purchases as per Invoice Register, Numbers 150 to 195.

When payment is made on account of creditors, the invoices are listed on a voucher check (Form 15) or on a remittance blank (Form 16). A record is made in the cash payments, and the amount is entered in the total and accounts payable column (Form 17). The items appearing in this column are posted to the debit of the various accounts in the Creditors' Ledger, and Accounts Payable is debited from the annual summary entry in the Journal. The total of the balances in the Creditors' Ledger equals the net balance of the controlling account in the General Ledger, if the work is correct. In auditing this account great care must be exercised to check the balances with the creditors' monthly statements.

ACCOUNT FILE SYSTEM.

Because of the extensive introduction of the duplicating and triplicating sales slips into the retail business, various account files have become very popular. They will be found entirely satisfactory only if used as a part of the system of general accounts, just outlined, and not as a substitute for it.

Of course the account file is used for personal accounts only—for customers and, sometimes, creditors. The triplicating sales slip is recommended. One slip is given to the customer and two filed—one in the register, and the third in a special checking file, after having passed through the cash register. The essential difference between this system and the ledger system just described lies in the fact that the balance due is forwarded from slip to slip, the last one being exposed, showing the balance due. Also credits of whatever nature are entered on this same style of slip, deducted from the last balance, and the resulting net balance forwarded as before. (See Form 22.)

In order to prove the accuracy of the register, the total of the last charge is listed from the triplicate (in the cash register) and a journal entry made exactly as before (Form 19). Likewise, the payments are listed and entered in the cash receipts, crediting the customers in the proper column (Form 14). Credits of produce are also listed on a register and journalized. The only difference lies in the fact that no posting to a customer's ledger is necessary, since the account file constitutes the customer's ledger.

When the controlling entries are posted, the total of the balances in the register will equal the net balance of the Accounts Receivable in the General Ledger, if the work is correct. Care must be taken not to allow the daily checking to lapse, because an error dating back several days is extremely difficult to find.

If the system is used also with the creditors' accounts, a special slip is used on which to forward the balances. A controlling account is kept in the General Ledger in the same manner as the customers' controlling account, and a journal entry is made of the total as often as desired. In this case, a special column would be necessary in the Cash Payments book with the heading "Accounts Payable," in which all payments to creditors would be entered. The individual items would be posted to the debit of the creditors' accounts, and the total posted to Accounts Payable at the end of the year in the same manner as the totals of the other columns. When this is done, the total balance in the register should equal the net balance in the controlling account.

DEPARTMENTAL COST ACCOUNTS.

For the purpose of determining the results of the various departments of the business and of setting up a satisfactory trading account, cost records should be kept with the different departments whenever practicable. Usually this record consists of only a few subdivisions of the Merchandise Account, such as Groceries, Dry Goods, Hardware and Implements. Entire bills are charged to the several accounts, so far as practicable, and bills which contain different classes of items must be segregated before they are paid and filed. The total of each division is then charged at convenient intervals to the departmental accounts. In a similar manner the sales are distributed and credited to the accounts. The triplicate copy of the sales slip will be found a convenient basis for the classification of credit sales. Either a cash register in each department or one register containing a departmental totaling device must be used in classifying cash sales.

The result, after taking into account the inventories at the beginning and end of the period, and after charging each department with its proportion of the overhead expenses, usually based on the turnover, shows the gain or loss of each department. A complete analysis of the gross cost, net cost, and general profits and losses of the business as a whole are found in the Manager's Report. The cost accounts are independent of the general accounts, and can be subdivided and modified at pleasure. However, they should check with the general trading account as prepared from the General Ledger (Form 7, II A). The usual stock ledger will be found a convenient form for the cost accounts.

AUDITING.

The object of the audit is threefold: (1) To serve as a check on the bookkeeper, so that a system of accounts, once established, be adhered to without deviation; (2) to serve as a reliable source of information to the stockholders as to the conduct and condition of the business, and accuracy of reports; and (3) the auditor should act as a counselor respecting business methods, especially pertaining to the office practice. The importance of the audit is often overlooked. No single factor will contribute more to the success of any corporate enterprise than a strict audit. It must not be forgotten that the auditor is primarily the servant of the stockholders, and not of the directors.

Many a cooperative enterprise has been wrecked because there has been no unity of policy respecting the methods of accounting and office practice. An unsatisfactory system of accounts is often better in the hands of an accountant who constantly keeps it up to date than the most perfect system in the hands of an inefficient bookkeeper.

A most important rule for the auditor to follow is to *allow no changes in the system of accounts, once established, except upon the written recommendation of the auditor, confirmed by the board of directors.* What appears to the bookkeeper or manager as an insignificant change may be of vital importance to the business.

A very erroneous opinion often exists regarding the duties and responsibility of an auditor. The auditor's principal duties are: (1) To check and verify the manager's and other officers' reports; to ascertain whether or not the reports are based on and agree with the permanent records of the business; (2) to verify assets and liabilities—first as to their existence, and, second, as to their value; and (3) to report on the system of accounts and the manner in which they are kept up.

It is not his duty to balance the books, nor to assist in preparing reports, nor is he responsible for bad accounting unless in his report to the membership he fails to call attention to the defects. Another important rule for the auditor to observe is to *require the complete balance sheet from the bookkeeper before he begins the audit.*

The best result will be obtained if the audits are neither too numerous nor too few. Perhaps a partial audit by a committee every three months will be sufficient, while a complete audit should be made once a year by an expert accountant or auditor.

It is very important that the auditor follow a definite routine in his work. Generally this should be as follows: (1) See that the reports are complete, in proper form, and in balance; (2) investigate any unusual item which may appear in the report; (3) check the report with the general ledger, and ascertain that the latter is in balance; (4) check the inventories and other schedules of accounts with the reports; (5) see that the valuation of both assets and liabilities is correct; (6) check the cash receipts (a) with the cash register, (b) with the original daily summary, (c) with the bank deposits (the total receipts must equal the deposits plus the change fund; the auditor should adopt a private mark, and check every item); (7) check the cash payments (a) with the original vouchers, (b) with the canceled checks, (c) as to distribution, (d) as to totals and balance; (8) check the journalizing and posting; (9) check the time sales and customers' ledger, if any, (a) with the original sales slips, (b) with the controlling account in the general ledger; (10) check the creditors' accounts in the same manner; (11) check the secretary's stock records; and (12) check the minutes, and see to it that nothing has been entered which is in conflict with them.

A complete audit consists of three parts: (1) Audit of the resources and liabilities; (2) the cash audit, and (3) audit of revenue. Whether or not it is possible for the auditor to complete such an audit satisfactorily depends on the condition of the books and reports when he takes them, and the time given to the work.

AUDIT OF RESOURCES AND LIABILITIES.

Because the solvency or insolvency of any business depends on the relation between the resources and liabilities, it is of the utmost importance that the truth of the Balance Sheet be shown. The method of determining this can be stated best by an example. Suppose the balance sheet of a cooperative store is as follows:

RESOURCES.		LIABILITIES.	
Cash.....	\$100.00	Capital Stock.....	\$10,000.00
Merchandise.....	8,000.00	Bills Payable.....	1,000.00
Accounts Receivable.....	3,000.00	Accounts Payable.....	2,000.00
Bills Receivable.....	1,500.00	Surplus.....	2,000.00
Real Estate.....	1,400.00		
Subscribed Stock.....	1,000.00		
	15,000.00		15,000.00

It is evident that if the resources are understated or the liabilities overstated, or both, the surplus is larger than \$2,000; and the reverse is true if there are more liabilities and less resources than appear on the statement.

The auditor must constantly take into account the weakness of human nature in the manager's disposition to show the business in the brightest light, and he must use every means at his disposal to verify the Balance Sheet. If satisfactory evidence of the statement does not exist, he should say so frankly in his report. The following are the several items of the Balance Sheet in their order:

Cash.—The method of verifying the cash has been given (page 51).

Merchandise.—It is usually impracticable for the auditor to examine every entry and every total of the inventory, but he should require that a proper classification be made under the various accounts found in the ledger, and he should appoint a responsible stockholder or assistant to be present at stocktaking who should also review prices, extensions, footings, etc. Every schedule should bear the O. K. of this assistant.

Accounts receivable.—The balance of the Customers' Ledger or Account File with the controlling account in the General Ledger is only partial evidence of the correctness of these accounts. Errors in prices, omissions of charges, and the like are not shown by this balance. The only satisfactory method of checking against such errors is a regular review of the triplicates by the bookkeeper, and also a check by the auditor of several sales slips of each day, week, or month, taken at random. If mistakes are very infrequent, and the total of the Customers' Ledger equals the controlling account, the Balance Sheet may be regarded as reasonably correct.

Bills receivable.—The balance shown in the General Ledger must equal the total of notes on hand. This should also be verified by

checking the notes on hand at the last audit and those received and paid during the period.

Real estate.—The real estate should be valued at the conservative market value, and sometimes it is advisable to examine deeds, mortgages, letters, etc.

Capital stock.—The capital stock must balance with the credit side of the Capital Stock Account in the Membership Ledger.

Bills payable.—A register is kept of Bills Payable if the business is extensive enough to warrant it (Form 24), and no entry is permitted in this book without the approval of the manager. The amounts not marked "Paid" must equal the total shown in the General Ledger.

Accounts payable.—The fact that the total balances in the Creditors' Ledger equals the controlling account balance in the General Ledger is generally taken as evidence of the correctness of the items. That this is not sufficient is evident from the fact that if a deferred item were either intentionally or accidentally omitted from the books or schedules, the amount would be a liability still, but the account would be short by that amount. *The only satisfactory method of proving creditors' balances is by the creditors' own monthly statements.* This is a precaution which is too often overlooked.

Surplus.—The surplus is made up of the several entries from the Journal at the close of each balance period.

There is a difference of opinion as to whether a single auditor or a committee should be employed. In most cases it is found that a single auditor is more satisfactory. In the average community, really competent accountants are scarce, and the greatest care must be exercised to avoid careless and perfunctory audits. It will be impossible to retain competent auditors without fair compensation; and the resources of the average cooperative association are such that the expense of an auditor will not be excessive. If the business warrants it, a certified public accountant should be employed. Generally, it should be a matter of indifference whether or not the auditor is a member of the association. In most cases, however, it is better if he is a nonmember. Perhaps the best results are obtained if the membership elect an auditing committee at the annual meeting, with the understanding that this committee employ a competent auditor.

OFFICE EQUIPMENT.

Too much attention can not be given to proper office equipment. Nothing discredits the store more quickly in the opinion of discriminating trade than slovenly appearance of the premises, and particularly an office littered with all kinds of rubbish, devoid of every convenience and comfort. Too often the opinion exists that a farm-

ers' store, in order to attract country people and make them feel at home, must avoid unnecessary decoration and the up-to-dateness which characterize the successful city retail store. On the contrary, the cooperative store should lead in everything which makes for greater comfort, refinement, and economy in business. Thus it can become a powerful educational influence in the community.

It should be emphasized that no great amount of money is required to keep the litter off the desk and counters and the cobwebs off the shelves. Many valuable conveniences can be improvised by the progressive bookkeeper and manager, and a duster costs practically nothing.

The first step in organizing any office, simple or complex, is to get things off the desks and counters *completely at least once a day*. This means filing; it means keeping things moving—papers, documents, books; it means continually applying the old adage, "A place for everything and *everything in its place*." Everything considered, the alphabetical vertical file will be found most satisfactory; one section for letters, another for invoices, a third for catalogues, a fourth for storing, etc.

Failure to index papers and material which are frequently referred to causes an enormous waste of time. This is due, generally, not to ignorance of proper method but to a lack of the application of common sense. Anybody can use a dictionary or a telephone index. There are no better models of good indexing. If drawers become numerous, number them and index the contents, thus saving the time and annoyance of frequent hunting for misplaced things.

Space does not permit more than a list of the desirable office conveniences which should be in every store. The cash register is an indispensable aid toward good business methods if used absolutely according to the manufacturer's and auditor's directions. Rather have no cash register at all than not to use properly the checks for accuracy which were the very origin of this valuable device. The register can be dispensed with when the business warrants the installation of an overhead carrier system. This system is often found to be one of the best investments in the store. Not only does it save a large share of the salesmen's time, but it makes for greater accuracy and general improvement in the office methods.

If properly used as an auxiliary to a system of records, the account file, referred to on page 48, is a great convenience. But it must never be forgotten that the account file is not a system of accounts; it must not replace the permanent consecutive records described in the preceding pages. As a file for short-account slips of 30, or at the most 60, days, properly safeguarded, it is a great labor-saving device.

A store can not long afford to do without a suitable adding machine. For listing sales slips, invoices, and countless items of computation

in a busy store it is indispensable. Only the listing machine is really serviceable. The smaller types, however, answer quite as well as the larger ones.

A typewriter is a great convenience. Duplicates of correspondence, orders, invoices, and other papers should be retained for reference, and this can be done best by means of the typewriter.

SUMMARY.

1. An adequate set of records is indispensable to any business.
2. The records must be comprehensive enough to analyze every important phase of the business; must be accurate and capable of proof, and must be kept up at all times.
3. An unsatisfactory system properly kept up is often more satisfactory than a perfect system improperly kept.
4. Records of like businesses should be standardized so that one business may profit by the experience of the others.
5. A system of accounts once adopted should not be changed without authority from the auditor and board of directors.
6. The financial statement is the foundation of any system of accounts.
7. Great care should be taken to decide on a correct classification of accounts before the system is adopted.
8. Sales, expenses, salaries, and other important facts should be reduced to percentages and studied closely by the management.
9. The cash should be checked daily from the cash register by the bookkeeper and monthly by the auditors.
10. Credit accounts, both for purchases and sales, should be avoided whenever possible.
11. All bills should be discounted, even if it becomes necessary to borrow money.
12. All cash receipts should be deposited.
13. All except petty payments should be made by check.
14. A good filing system is indispensable.
15. All time sales should be recorded on triplicating sales slips.
16. Dividends should be paid on cash business or accounts settled within 30 days either in cash or produce.
17. The president, manager, and auditor should each be required to submit an annual written report.
18. The audit should be regular, comprehensive, and thorough.
19. The auditor should refuse to enter upon the audit until the balance sheet is submitted by the bookkeeper.
20. Special diligence should be exercised by the auditor to discover resources and liabilities not properly included in the statement.
21. Whenever possible a certified public accountant should be secured to make the annual audit.

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**BULLETIN No. 382**

Contribution from the Bureau of Entomology
L. O. HOWARD, Chief

Washington, D. C.



July 8, 1916

**COTTON BOLL-WEEVIL CONTROL IN THE MISSISSIPPI
DELTA, WITH SPECIAL REFERENCE TO SQUARE PICK-
ING AND WEEVIL PICKING.**

By B. R. COAD,

Entomological Assistant, Southern Field Crop Insect Investigations.

INTRODUCTION.

In devising measures for the control of the boll weevil the experience of the Bureau of Entomology has shown that those which are practicable in one region do not necessarily apply in another. The conditions vary according to climate, topography, and systems of agriculture. Each locality offers peculiar conditions, but striking differences occur between the cotton regions of Texas and of the delta of Louisiana and Mississippi. These varying conditions have led to the development of rather distinct methods of control of the weevil, as applied to these two regions.

During the progress of the Mexican cotton boll weevil northward and eastward across the State of Texas, a combination of control measures which was reasonably effective in limiting the damage to the cotton crop was devised and adopted. These measures were largely of a more or less indirect nature, such as planting early maturing varieties, frequent shallow cultivation, wide spacing of the plants to allow the sunshine to reach the fallen squares, etc. Largely owing to the comparatively dry climate and the exceedingly high mortality of the weevil stages in the fallen forms, produced by the hot sunshine, these measures generally sufficed for that region. When the weevils invaded the Delta region of the Mississippi River, in the States of Louisiana and Mississippi, however, it was found that weevil control was complicated by new conditions. The extremely heavy rainfall and high humidity prevailing in the Delta region, together with the rank vegetative growth typical of the cotton plants there, combined to reduce greatly the most important factor in the

NOTE.—This bulletin is intended to give practical advice to the cotton raisers of the Mississippi Delta on the subject of controlling the boll weevil.

natural control of the weevil, namely, the mortality produced by heat in these fallen forms. The ground remained so moist between the rows in many fields for considerable periods that the weevils were able to mature under the most favorable conditions and consequently to multiply prolifically.

To meet these new conditions various direct control measures have been devised and practiced. The most popular of these consisted of the collection of the overwintered weevils from the plants in the spring and the gathering and destruction of the fallen infested forms from the ground. These operations are commonly termed "weevil picking" and "square picking," respectively. They are based on the fact that the most critical period in the yearly cycle of the weevil and the time at which its numbers reach the lowest ebb is in the spring when the comparatively few survivors of the winter are emerging. In an average season these overwintered weevils are relatively scarce, and it is not until their progeny begin to mature and multiply that the actual severe damage to the cotton is produced. Owing to the very high fecundity of the individual females, each overwintered weevil destroyed early in the spring means the elimination of an enormous number of potential progeny in the later generations, and, in the same way, the collection of the immature stages of the weevils of the first-bred generation in the fallen forms not only reduces the weevil abundance by the actual number collected but also retards further multiplication. Because of these facts a number of cotton planters have considered it a paying proposition to incur a considerable expense per acre to destroy these early weevils. It was found, however, that the results secured by the different planters practicing these control measures varied widely and their conclusions as to the actual benefit derived were equally diverse. Many claimed very positive gains while many of their neighbors operating under much the same conditions could see no benefit from the measures and considered the expense thus incurred an absolute loss.

Another factor enters into the problem and further complicates matters. This is the question of labor supply. Under the conditions at present prevailing in the Delta the available labor, during the months of May and June, is always more or less short of the labor needed. In addition to this, one very important effect of the weevil on the economic system of this region has been the forcing of diversified farming instead of the old one-crop system. The new crops most generally adopted were corn and oats. As a result the labor crisis during the spring period has become even more acute. Not only does the cotton require cultivating and hoeing, but it is also necessary to cultivate and hoe the corn and cut, shock, haul, and thrash the oats

during this same period. None of these operations could be neglected without a serious loss to the plantation. As these all fall at the time when it is necessary to perform the weevil-picking or square-picking operations it has become more and more necessary to determine the actual benefit derived from these control measures and to ascertain to what extent it would be profitable to slight the other operations in their favor. A series of studies was, therefore, inaugurated at the Delta Laboratory located at Tallulah, La., in the effort to secure definite information on these points. These studies were largely conducted on an experimental basis, but their results were checked by observations on the plantation use of the different control measures. The following is a brief consideration of the points brought out by these studies.

SQUARE PICKING.

The first of the studies consisted of plat tests on the effect of picking only the fallen forms during the spring. The first picking was made as soon as the fallen forms had reached a considerable number and still before the weevils had started to emerge from them. As the emergence of the weevil from hibernation was exceedingly late during the season when this test was conducted (1915), it did not prove necessary to conduct this first picking until June 16. Of course this date of picking would vary widely with the season, and in a year of normal emergence it would undoubtedly be much earlier. Following this the plat was carefully picked over every 7 days until July 14, a total of five pickings, extending over a period of 28 days. During this time 42,672 forms per acre were collected. In actual bulk this equaled about 42 gallons per acre. The method of picking used was the simplest possible. Mixed negro laborers were provided with sacks for holding the forms and were sent down the rows to gather all forms from the ground by hand. The picking was carefully supervised in order to make sure that the collections were thorough.

The weevil infestation in these plats was followed carefully throughout the season and it was soon found that the infestation in the picked plat was showing a very decided effect from the operation. For example, on July 6, 18 per cent of the squares in the picked plat were infested, while 44 per cent were infested in the untreated check plat. On July 13, the percentages were 37 and 63, respectively. In fact all observations consistently demonstrated that the square collection was reducing the weevil infestation within the treated plat. Of course the final criterion determining the effect of the operation was the production, and it was found that the picked plat produced 23 per cent more seed cotton per acre than the check. However, this

gain in yield must not be considered as being net profit, since there are certain expenses to be charged against the value of this increased production. These are the actual labor involved in the control operation and the effect of diverting the labor from the usual operations to those of weevil control.

Careful studies were made on the labor involved in these square pickings and the figures secured from the experimental tests were also checked under conditions more closely approximating those of plantations. From these studies it was found that the average labor per acre involved in the pickings ranged from about 4 hours for the first to about 24 hours for the fifth. The general average of all the pickings was slightly over 11 hours per acre per picking. As the labor day in the Delta section is usually of about 12 hours during the spring, this indicates that the pickings would average about 1 day's labor per acre, or a total of 5 days for the five pickings. As the greater part of the picking is done by women and children, this labor probably has a value of not more than 50 cents per day on the average. This would make the five pickings cost about \$2.50 per acre on a wage basis. Of course this labor will vary greatly with the locality, field, and seasonal conditions, as these factors will determine the number of fallen forms present to be picked. Heavy infestation, producing a large number of fallen infested forms, will, of course, require much more labor per acre to control, while a lighter infestation, particularly on thin, sandy land, where the square formation is not so profuse, will result in comparatively few forms to be collected, and the labor required will be lessened. Under certain conditions of soil and climate there is frequently a very heavy shedding of uninjured forms. Of course these can not be distinguished from the infested forms when on the ground, and must be gathered. This condition occasionally becomes so pronounced that it greatly increases the labor involved in picking.

The time interval between pickings in this test (7 days) was selected arbitrarily, but it is probably about the most satisfactory period. This gives an interval sufficiently short to prevent any considerable weevil emergence from the fallen forms between pickings and is still about as long as can be safely allowed. The number of pickings must depend entirely on the conditions prevailing. The object of the number utilized in this test was to cover the period from the first falling of squares in considerable numbers to the time when the work becomes too bulky to handle. As previously mentioned, in an ordinary year the operation would probably start earlier than was necessary in 1915, but, owing to the rapid increase in the labor required during the later pickings, it would probably not be profitable to give more than four pickings under ordinary

conditions. If any benefit is going to be derived, it should be secured during this period, and the cost of the operation will be sufficiently low to allow a reasonable margin for profit. It seems hopeless to expect to prevent all weevil multiplication in the field, regardless of how thoroughly the picking operations are conducted, and the best that can be hoped for is to retard the time when the practically complete infestation of squares is reached, thus allowing a slightly longer period for the formation of fruit and the safe maturing of the bolls which have already been set.

The disposal of these infested forms is an important item. Based on the conditions which prevailed in the more western territory, where the parasitic control of the weevil is a considerable item and where smaller amounts of forms are collected, it was recommended that they be placed in screen cages, instead of actually destroying them, thus allowing the emergence and escape of the weevil parasites in these forms and still retaining for later destruction the weevils maturing from them. In the Delta, however, the conditions are so different that this recommendation is not advisable. Parasitic control of the weevil in the Delta is generally so low that it is of little importance, and therefore comparatively few parasites would be saved by this means. In fact, unless rather elaborate and expensive precautions were taken to prevent the weevils' escape from these cages it seems probable that a sufficient number of weevils would be released to more than offset the parasites saved. This consideration is further emphasized by the carelessness of the negro laborer. In addition, the quantity of forms handled in the Delta is so great that the expense of providing cages for their disposal is practically prohibitive. It has already been shown that in the plat tests of 1915 an average of 42 gallons of forms were collected per acre. When it is considered that many of the Delta planters reckon their cotton acres by the hundreds and even by the thousands, it is easy to see what an enormous task it would be to provide screen cages for these forms. In view of these facts it seems advisable to dispose of these forms in the quickest and most effective manner possible. This may be done quite easily by burning or burying them.

WEEVIL PICKING.

There are a number of different methods of collecting the adult weevils from the cotton, but it is probably best to consider only those most prevalent in the Delta. In earlier years practically the only method practiced was what is now termed "hand picking." In following this method the laborers were each given a box or a bottle and they depended entirely upon being able to see and capture the adult

weevils on the plants. This method was exceedingly slow and laborious and, owing to the large number of weevils actually overlooked, and the additional number escaping by "possuming" and falling to the ground upon the first disturbance of the plant, this method was not very effectual. Within the last few years, however, a semimechanical method of collection has been devised by some of the Delta planters and its use has spread rapidly. This is what is commonly termed the "bag-and-hoop," or "hoop-and-sack" method of collection. It consists of shaking the plants into a sack, the mouth of which is held open by a barrel hoop. This method proved to be much more effective and less expensive than hand picking.

To determine the relative efficiency of these two methods of weevil collection a number of comparative tests were conducted. These show the hand picking to require four times as long as the bag-and-hoop, while the latter collected more than twice as many weevils as the hand picking from the same area. In addition to this, in the course of the weevil collection with the bag-and-hoop a large number of infested forms are gathered, thus making the operation in reality a combination of weevil picking and square picking. Thus it can readily be seen that there is no question of the great superiority of the bag-and-hoop method over hand picking.

The apparatus required for the bag-and-hoop collections is the simplest possible. A burlap seed sack with a barrel hoop some 24 inches in diameter sewn into its mouth is all that is necessary. A tub or barrel of water with a small amount of kerosene on its surface may be placed on the turnrow and the bags emptied into it about every second row.

It was found that there was considerable difference in the results secured from the different methods of handling this bag-and-hoop. Comparative observations have shown the following to yield the best results: The bag should be placed against the base of the cotton stalk with as little disturbance as possible. Then the plant should be gently bent well into the mouth of the bag and shaken several times rather sharply from side to side, that is, at right angles to the length of the bag instead of back and forth into its mouth. It was found that there was considerable difference in the weevils collected when these two methods of shaking the plant were compared. As a result of shaking the plant lengthwise of the bag a number of weevils are evidently thrown away from the bag instead of into it, while other weevils actually thrown into the bag strike against the hanging back and bounce out again. On the other hand, when the plant is shaken across the sack, all weevils falling from it are retained.

More elaborate devices resembling the bag-and-hoop in principle were tested, but it was found that none of these was as efficient as

the simple form just described and that all possessed the additional disadvantage of being more expensive to make.

Observations were made to determine the time required per acre for the operation of the bag-and-hoop, and it was found to vary widely with the individual laborer, but the general range was found to be from 1 to 2 acres per hand per day. Of course the operation would be more rapid during the early pickings when the plants are small and weevils are rather scarce. The figures secured, however, seem to indicate that from 1 to $1\frac{1}{2}$ acres per laborer per day is the best average that can be expected throughout the picking season. On a day-wage basis this would mean an average expenditure of some 40 to 60 cents per acre for each picking, and if the pickings were continued very late into the season this expense would be considerably increased.

The time interval between pickings which will yield the best results is still open to question, but it seems advisable to make it shorter than that between square pickings in order to reduce the time for square puncturing allowed the weevils, and also to reduce the number of infested forms falling to the ground between pickings, thus securing the benefit of both square picking and weevil picking. The studies to date seem to indicate that better results will be secured from several pickings given early in the season with a short time interval than where the same number of pickings are extended over a longer period by making the time interval a week or more. In fact, when the labor supply is not sufficient to allow this intensive treatment of all of the cotton it seems probable that better net results would be secured by concentrating the labor on only a portion of the crop and allowing the remainder to go untreated. In the case of cotton worked by wage labor the control measures could be concentrated on certain cuts, while in a case of tenant cotton the thorough and consistent picking of a portion of a cut would probably be more profitable than scattering the same amount of labor over the entire cut, in a series of more or less irregular and haphazard pickings. This concentration of effort, however, would not apply in a season of exceedingly heavy weevil infestation when the available food supply on the near-by untreated cotton would soon be exhausted and the weevils would migrate into the picked cotton in search of food. Except under these conditions, however, the early season interfield movement of weevils is apparently sufficiently slight to allow their control within a comparatively small area.

GENERAL CONSIDERATIONS.

The foregoing discussion has been devoted to the consideration of the best methods of picking weevils and squares, and the figures have been based on a day wage scale. There now remains to be considered

the application of these facts and figures to plantation conditions. In the first place there is little or no picking on a day wage basis, but it is practiced under the tenant system where no actual cash outlay is required and the only expense of the operations is that incurred by the detrimental effect produced on either the cotton or some other crop because of taking the labor from its care and utilizing it in these weevil control measures. Consequently, the question is just how much the planter can afford to slight the other operations in order to pick his squares or weevils. Studies on the increased yields produced by these control measures have shown that there is a very definite advantage. However, very little neglect of the cultural operations may produce a loss amply sufficient to more than offset any benefit derived from the reduction of the weevil infestation. For this reason it seems generally inadvisable to practice these control measures except in the presence of an abundance of labor.

Because of this complication with the labor supply the greatest desideratum at present is the perfection of a mechanical means of weevil picking which will be as effective as the bag-and-hoop method and still will allow the handling of a considerable number of acres per day per hand. Several mechanical devices were tested in comparison with the bag-and-hoop and, while none of them was as efficient as the latter method, one or two gave some promise of satisfactory results with further improvements in their construction. It should be stated that there are a number of serious problems to be met by a mechanical picker, which make it still doubtful as to whether a satisfactory one can be devised. In the first place the question of interruption of operations by rainy weather is a serious problem. A number of successive rainy days resulting in continually muddy fields produces the best possible conditions for weevil multiplication and thus necessitates even more strenuous efforts for control, but the same conditions make it difficult to operate mechanical pickers in the field. Such weather conditions are met with practically every spring in the Delta. The necessity for drainage in this region causes the cotton to be planted and worked on "ridges." This raising of the plants above the middle of the rows interferes seriously with the operation of many mechanical pickers. In addition to this, as long as the present system of laying off and planting rows is followed there will always be more or less crooked rows and the distances between the rows will vary considerably. This condition presents another obstacle to mechanical pickers, particularly those taking two rows at a turn. Still another obstacle is the difficulty in operating many of these machines in irregular, stumpy land such as is found on some parts of almost every plantation in the Delta. These fields are the ones which have been cleared only recently and

with proper protection from the weevils would make far better cotton crops than the land which has been in cultivation for a longer period. Considering these obstacles to be overcome and the degree of efficiency in weevil collection which must be developed by a mechanical picker, it is easy to see that there will be great difficulty in developing a satisfactory one.

One factor in the relation of these weevil-picking measures to the plantation complex is the effect upon the labor itself. On many plantations it is desirable to have the laborers conduct some direct control measures in order to encourage them to work the crop thoroughly. In such cases the bag-and-hoop method seems to satisfy the needs very well. The laborers can capture a considerable number of weevils and the fact that they are actually destroying these weevils often seems to encourage them greatly. In fact, a number of planters who practice this control measure state that they do not consider that they are deriving any direct benefit from the reduction in weevil infestation, but that the operation is worth while because of its beneficial effect upon the morale of their labor.

SUMMARY AND CONCLUSIONS.

Plat tests of five square pickings at seven-day time intervals gave an increased yield of 23 per cent over the check.

Tests of seven weevil pickings with the bag-and-hoop indicated similar results.

The seasonal conditions obtaining during the course of the experiments described in this bulletin have been referred to; it is possible that different seasonal conditions might yield different results.

Comparative observations on different methods of collecting weevils demonstrated the great superiority of the bag-and-hoop over hand picking so definitely that there should be no question as to which method to follow.

The margin of profit to be derived from these two control measures seems to be too slight to allow their operation on a wage basis. For this reason the only condition under which they should be attempted is on tenant cotton where the work can be performed without any direct outlay for labor.

Owing to the shortage of labor in the Delta these operations are very likely to interfere seriously with the regular plantation work and thus cause a loss more than sufficient to offset any benefit derived from them. In such cases it is not advisable to attempt to pick either squares or weevils.

In case it is necessary to choose between a cultivation and a weevil or square picking, cultivate.

If, after considering the foregoing points, it seems advisable to practice either of these control measures, the following seem to be the best methods:

Square picking.—A time interval of about seven days between square pickings seems advisable.

The first picking should be made within a week of the time when the squares start to fall in considerable numbers.

It is not likely to prove profitable to pick squares more than four or five times.

The squares should be disposed of as soon as possible after collection by burning or burying.

Weevil picking.—The most satisfactory method of weevil picking now known is the bag-and-hoop.

The first picking should be made as soon as the weevils are sufficiently abundant to make the operation worth while. This is likely to be about the time the plants start squaring or soon thereafter, although in exceptional cases it is not necessary to pick until considerably later.

Following this the pickings should be made as frequently as possible—twice a week, if practicable.

It is not likely to prove profitable to make more than four to six pickings at the most.

Of these two measures the bag-and-hoop is likely to prove the more profitable under usual conditions and is really the easiest and simplest method to practice.

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UNITED STATES DEPARTMENT OF AGRICULTURE



BULLETIN No. 383

Contribution from the Bureau of Plant Industry
WM. A. TAYLOR, Chief.



Washington, D. C.



August 15, 1916

NEW SORGHUM VARIETIES FOR THE CENTRAL AND SOUTHERN GREAT PLAINS.

By H. N. VINALL, *Agronomist*, and R. W. EDWARDS, *Scientific Assistant, Office of Forage-Crop Investigations.*

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INTRODUCTION.

New varieties of sorghum are constantly appearing, and nearly every year one or more are exploited. In many instances these are well-known forms masquerading under new names, but there are also a large number which are truly different from those in common cultivation. One prolific source of these new sorghums is the cross-pollination which takes place naturally between different varieties. The sorghums being open fertilized and the pollen readily carried by the wind, there is abundant crossing between varieties whenever two kinds which are being grown in adjoining fields come into bloom at the same time. Occasionally, also, new strains are brought over from foreign countries by friends or relatives of residents of the United States. In addition to the varieties which arise in a more or less spontaneous manner, a large number have been introduced for trial through the Office of Foreign Seed and Plant Introduction, and many are created in the breeding work of the United States Department of Agriculture and the State agricultural experiment stations.

Among the resultant host of new forms, remarkably few are found of sufficient value to compete successfully with the best standard

varieties, such as Blackhull kafir, Dwarf milo, Orange sorgo, and Sumac sorgo.

Farmers should be slow to discard the standard varieties for new ones. A small acreage of the less known variety should be grown first for comparison, or the recommendations of the State agricultural experiment stations or of the United States Department of Agriculture, should be followed in the matter of adopting the newer sorts. In order to be in a position to advise farmers in regard to these new varieties the experiment stations conduct extensive variety tests.

Breeding work with the sorghums is a complex process, owing to the freedom with which they cross-pollinate and the resulting difficulty of establishing a stable variety. A farmer can rarely afford to engage in creative plant-breeding work; that is, the production of new varieties by cross-pollination. This assertion is based on several reasons: (1) The percentage of success is very small, that is, the breeder must expect to discard numberless forms before one is found that will be of sufficient value to replace the varieties now being grown; (2) the development of a variety yields little profit to the originator, because he can control neither its propagation nor its distribution; (3) the farmer is working at a disadvantage when compared with experiment stations, because in most cases he lacks a knowledge of the range of existing forms available as a basis for his breeding work; (4) extreme care and patience are necessary in plant breeding, and if the farmer devotes to it the required time his general crops are likely to be neglected and financial loss ensue.

The devotion of a farmer's time to creative plant breeding can be justified, therefore, only from an altruistic standpoint. Unless his income is assured from outside sources, it is unwise for him to engage in plant breeding except in the improvement of the standard varieties by consistent seed selection. This phase of crop improvement is well worth his time and effort.

DESCRIPTION AND ADAPTATION OF THE NEW VARIETIES OF SORGHUM.

Most of the new varieties of sorghum described in this bulletin were obtained by selection from importations made by the United States Department of Agriculture, but others have been picked up among farmers, and their exact origin is obscure. All of these have given very satisfactory results in experimental trials, and a few of them are already grown locally by farmers. In view of these facts they are deemed worthy of wide distribution, so that they may be tried under field conditions in competition with the varieties usually grown.

Typical plants of Dwarf hegari, Improved feterita, and Schrock kafir are shown in figure 1, and figure 2 shows the comparative sizes and shapes of the heads of all the varieties.

DWARF HEGARI.

Dwarf hegari is a selection (F. C. I. No. 4201) from S. P. I. No. 22326, which sorghum was obtained from the agricultural inspector at Khartum, Sudan, Africa, under the native name of Hegari. Dwarf hegari is a short, leafy strain chosen from the above number at the Forage-Crop Field Station, Chillicothe, Tex., in November, 1910.

Description.—Stems stout, five-eighths to three-fourths of an inch in diameter, 4 to 5 feet tall, medium juicy, slightly sweet, usually with but few tillers and only occasional branches; leaves 12 to 14, averaging about 3 inches broad and 24 inches long; head cylindrical to ellipsoidal, erect, medium compact, 3 inches in diameter, 7 to 8 inches long, usually well filled, exerted 2 inches



FIG. 1.—Typical plants, showing the character of the stem, leaf, and seed head: 1, Dwarf hegari; 2, Improved feterita; 3, Schrock kafir.

above the upper sheath; seeds spherical, medium sized, white, marked with a few red and brown spots, the upper two-thirds exposed from the glume, shattering moderately; glumes ovate, black, slightly pubescent, not awned.

In general appearance Dwarf hegari resembles Dwarf Blackhull kafir very closely (fig. 1), but is nearly intermediate between it and feterita in the compactness of the panicle or head, in the size and markings of the seed, and in germinating power. It stands up well in storms, lodging very little. The growing season averages 96 to 100 days under normal conditions on the Great Plains.

This variety has become well known in the vicinity of Chillicothe, Tex., and the acreage has increased rapidly in the past two years. Many farmers prefer it to Dwarf milo on account of its higher forage value and the greater ease of harvesting due to the erect heads. Its early maturity has caused it to be looked upon favorably as far north as central Nebraska.

IMPROVED FETERITA.

Improved feterita (S. P. I. No. 22329) was obtained from the Sudan region of Africa in 1908, two years after the first successful importation of this sorghum. Since its introduction it has been improved by selection, and in field trials has shown a consistently higher yielding power and more uniform growth than the earlier importation (S. P. I. No. 19517), from which most of the feterita now being grown in the United States has come.

Description.—Stems medium to stout, five-eighths to three-fourths of an inch in diameter, 5 to 6 feet tall, with little or no juice, only slightly sweet, and having few tillers and only occasional branches; leaves 10 to 12, averaging $2\frac{1}{2}$ to 3 inches broad and 20 to 22 inches long; head ovoid to ellipsoidal, erect,



FIG. 2.—Seed heads of the new varieties of sorghum, showing their size, shape, and color. The measure (at the left) is graduated to inches and fractions thereof. From left to right: White milo, Dwarf hegari, Improved feterita, Dwarf feterita, and Schrock kafir.

medium compact, 3 to $3\frac{1}{2}$ inches in diameter, 7 to $7\frac{1}{2}$ inches long, usually well filled, exerted 2 to 3 inches above the upper leaf sheath; seeds circular in outline, slightly flattened, large, white, the upper two-thirds exposed from the glume, shattering rather easily; glumes ovate, black, slightly pubescent, not awned.

Improved feterita, except for its greater uniformity and consequent shorter growing season, averaging about 90 to 100 days, does not differ from the ordinary feterita now so widely grown throughout the Great Plains (fig. 1). Compared with Dwarf feterita, this selection has a somewhat heavier stalk and appears to be more leafy, giving it a higher forage value than Dwarf feterita under most conditions (fig. 3).

DWARF FETERITA.

Dwarf feterita is a selection (F. C. I. No. 811) from S. P. I. No. 22329. The plant selected in 1909 by the senior writer at San An-

tonio, Tex., was only $2\frac{1}{2}$ feet high and was fully mature two weeks in advance of the general crop of feterita. It has not fully retained either its dwarfness or its earliness, but seems each succeeding year to be nearer the type of ordinary feterita, so that rigid selection appears necessary to maintain its distinctiveness.

Description.—Stems medium to slender, one-half to five-eighths of an inch in diameter, $4\frac{1}{2}$ to $5\frac{1}{2}$ feet tall, slightly sweet, scarcely juicy, usually with but few tillers, and only occasional branches; leaves 9 to 10, averaging 2 to $2\frac{1}{2}$ inches broad and 18 to 20 inches long; head ovoid to ellipsoidal, erect, medium compact, 3 inches in diameter, 6 to 7 inches long, usually well filled, exerted 4 inches above the upper leaf sheath; seeds circular in outline, slightly flattened, large, white, the upper two-thirds exposed from the glume, shattering rather easily; glumes ovate, black, slightly pubescent, not awned.



FIG. 3.—The first cutting of the two new varieties of feterita at Chillicothe, Tex., in 1914. Dwarf feterita (at the left) and Improved feterita (at the right). Plats planted on April 21. Photographed July 20.

Dwarf feterita in its present form has a rather more slender stalk than ordinary feterita, and the head is a trifle smaller. It ripens about 4 days earlier, the growing season averaging 88 to 96 days, but except for the size of the plant, the length of the growing season, and its greater uniformity there is no difference between it and ordinary feterita. As is also the case with Dwarf hegari, two seed crops of Dwarf feterita can sometimes be harvested in one season (fig. 4). This variety of feterita would seem to be of value as an insurance against drought. At Amarillo, Tex., in 1913, when practically all the kafirs and milos were failures, this variety headed out at a height of $2\frac{1}{2}$ to 3 feet and made a grain yield of 15 bushels per acre when ordinary Blackhull kafir under exactly similar conditions produced hardly a head (fig. 5).

WHITE MILO.

The exact origin of White milo is in doubt, but it seems probable that the variety as it is now being grown in the United States originated from certain importations of sorghums from India. Several sorghums very similar in character to the common White milo were included in a shipment received by the United States Department of Agriculture in 1903, and it is easy to believe that such differences as exist in the two forms may have come about through a process of seed selection carried on by farmers.



FIG. 4.—Second cutting of the two new varieties of *feterita* at Chillicothe, Tex., in 1914. Dwarf *feterita* (at the left) and Improved *feterita* (at the right). The first cutting was removed on July 25. Photographed October 15.

In the early history of sorghums in this country the name White milo, or more often "White milo maize," was associated with "Rural Branching sorghum." This sorghum, however, from descriptions and specimens preserved, proves to be a kafir rather than a milo. The present strain, on the contrary, is a true milo, having the transverse corrugations on the glume and other distinctive marks of the milo group. True White milo appears to have been grown locally in northern Texas for several years, but its history in this locality is vague. Seed of what appeared to be a dwarf strain of this true White milo was obtained in 1911 by Mr. G. E. Thompson, at that time superintendent of the Forage-Crop Field Station at Chillicothe, Tex. This strain (F. C. I., No. 5886) has been grown at that station with good results since that time, but like the Dwarf *feterita* it does not appear to maintain its dwarf characteristics without continued selection.

Description.—Stems medium to slender, one-half to five-eighths of an inch in diameter, $4\frac{1}{2}$ to $5\frac{1}{2}$ feet tall, lacking both juice and sweetness, having no branches and but few tillers; leaves 12 to 13, about $2\frac{1}{2}$ inches broad and 22 to 26 inches long; head ovoid, mostly erect, sometimes recurved, compact, 3 to 4 inches in diameter, 5 to 6 inches long, usually well filled, exerted 4 to 6 inches above the upper leaf sheath; seeds slightly flattened, medium to large, white, the upper three-fifths exposed from the glumes, shattering little; glumes broadly ovate to orbicular, red-brown to greenish gray, slightly pubescent, awned.

White milo is taller and rather more slender than ordinary Dwarf milo, and only about 20 per cent of the seed heads are recurved in ordinary plantings. The seed except for its white color resembles that of ordinary Dwarf milo very closely, but it is usually mature a



FIG. 5.—Ordinary Blackhull kafir (at the left) and Dwarf feterita (at the right), showing the superior ability of the feterita to make a seed crop under conditions of extreme drought. Amarillo, Tex., 1913.

few days earlier, the average growing season for the crop being 88 to 96 days. White milo seems to share with feterita the ability to make a seed crop under deficient moisture conditions.

SCHROCK KAFIR.

The Schrock variety of kafir, which is difficult to classify on account of its rather peculiar combination of characters, was discovered by Roy Schrock, a mail carrier at Enid, Okla., in 1912. Seeing a vigorous and very heavily seeded plant growing in a field along his route, he gathered the seed and took it home to plant the following year. In 1913 Mr. Schrock grew a row of it in his garden and sent a sample to the United States Department of Agriculture for identification. It appears to be a hybrid between some kafir and a sweet sorghum, very likely Black Amber.

Description.—Stems stout, three-fourths to 1 inch in diameter, $4\frac{1}{2}$ to 5 feet tall, medium juicy, rather sweet, with only occasional branches and few tillers;

leaves 12 to 14, averaging 3 to 3½ inches broad and 24 to 28 inches long; head club shaped, erect, medium compact, 3 to 3½ inches in diameter, 7 to 8 inches long, usually well filled, the base of the head sometimes inclosed by the boot; seeds ovoid, slightly flattened, medium sized, brown, the upper one-third or one-fourth exposed from the glume, shattering very little; glumes ovate, black or dark red-brown, glabrous or slightly pubescent, not awned.

Schrock kafir has leaves as broad and somewhat longer than those of Blackhull kafir, so that the plant presents an exceedingly leafy appearance (fig. 1). The head is about the same size, but not so compact as that of the ordinary kafir. The seeds are pointed at the tip, like those of the sweet sorghums, and are like them also in that they contain a noticeable percentage of tannin. The stem and leaves remain green until the seed is ripe, and even the tillers will mature before the main stalk shatters its seed. It requires from 100 to 120 days to mature fully, which will prevent the successful production of this variety north of Kansas. Schrock kafir has been tested with the idea that it might be found valuable for both grain and fodder, but the tannin in the seed lessens its value as a grain crop.

Figure 2 shows typical heads of all five of the varieties described in this bulletin and gives an idea of their size, shape, and color.

COMPARISON OF THE FIELD RECORDS OF THE NEW SORGHUM VARIETIES.

For the past three or four years Dwarf hegari, Dwarf feterita, Improved feterita, and White milo have been grown at three field stations in the Great Plains region in comparison with standard varieties of kafir, milo, and sorgo. As a result of these trials the new varieties are being distributed to farmers in order to obtain their judgment on the usefulness of these sorghums. The figures on yields of forage and seed, with statements regarding stands, height of plants, and length of the growing season, for Chillicothe, Tex., Amarillo, Tex., and Hays, Kans., respectively, are given in Table I. The size of the plats used in obtaining these data is stated in connection with the table. The yields of fodder are given in terms of field-cured material in all cases except at Hays, Kans., in 1915, where the moisture content in the fodder was corrected to a uniform basis by means of air-dried samples.

TABLE I.—*Comparative growth and yield of the new and of standard varieties of sorghum at two stations in Texas and one station in Kansas in 1913, 1914, and 1915.*

Place, year, and variety.	Serial No.	Season.	Row space.		Height.	Acre yield.	
			Plant.	Stalk.		Fodder. ¹	Grain.
AT CHILLICOTHE, TEX.							
1913 (very dry season):		Days.	Inches.	Inches.	Inches.	Tons.	Bushels.
Dwarf hegari	4201		18		43	1.04	(²)
Dwarf feterita	811	111	27		48	.97	10.71
Improved feterita	22329		19		50	.80	8.03
Standard feterita	19517	110	21		55	1.04	10.71
White milo	5886	109	16		44	1.10	17.5
Dwarf milo	18684	113	20		33	1.12	11.9
Dwarf kafir	24983				43	1.05	(²)
Blackhull kafir	17569		14		33	.95	(²)
1914 (medium season):							
Dwarf hegari ³	4201	89	10		48	6.10	56.6
Dwarf feterita ³	811	92	7.8		54	4.95	53.5
Improved feterita ³	22329	96	7.7		57	6.05	51.5
Standard feterita ³	19517	101	8		68	5.85	40.8
White milo	5886	91	6.9		60	3.06	21.3
Dwarf milo ³	18684	96	7.1		42	4.83	41.1
Dwarf kafir	24983	102	7.3		42	2.60	13.1
Blackhull kafir	17569	104	6.9		48	3.85	12.5
1915 (very wet season):							
Dwarf hegari	4201	104	9.1	7.3	58	4.54	38.4
Dwarf feterita	811	83	9.1	6.9	54	2.52	28
Improved feterita	22329	84	8.3	6.5	57	2.47	27.3
White milo	5886	85	9.4	6.7	58	2.37	32.5
Dwarf milo	18684	101	7.9	5.8	50	3.60	36.8
Dwarf kafir	24983	101	8	6.6	51	3.20	28.6
Blackhull kafir	17569	114			63	4.27	39.82
Schrock kafir	1481	99	7.4	5.8	58	3.87	46
Average, 1913 to 1915: ⁴							
Dwarf hegari	4201	97	12.3		49	3.89	31.7
Dwarf feterita	811	88	14.6		52	2.81	30.7
Improved feterita	22329	90	11.6		55	3.11	28.9
Standard feterita ⁵	19517	106	14.5		61	3.44	25.7
White milo	5886	88	10.8		54	2.18	23.8
Dwarf milo	18684	99	11.6		42	3.18	29.9
Dwarf kafir	24983	104	7.6		45	2.28	13.9
Blackhull kafir	17569	109	10.4		48	3.02	17.4
AT AMARILLO, TEX.							
1913 (extremely dry season): ⁶							
Dwarf hegari	4201	90	3	2.5	20	.50	0
Dwarf feterita	811	81	11	5	34	1.10	14.70
Improved feterita	22329	81	12	4.8	46	1.20	24.10
Standard feterita	19517	84	10	4.7	36	1.28	13.10
Dwarf milo	18684	97	6	3.9	24	1.03	2.07
Dwarf kafir	24983	110	13.3	7.4	28	.45	0
Blackhull kafir	17569	120	4.5	2.6	34	1.33	0
1914 (medium season): ⁷							
Dwarf hegari	4201	90	5	2	43	3.18	25
Dwarf feterita	811	90	7.8	2.6	55	2.87	28.5
Improved feterita	22329	92	8.4	3.1	55	2.09	14.1
Standard feterita	19517	92	11.8	4.3	54	2.16	13.8
White milo	5886	94	6.2	2.4	52	1.93	20.4
Dwarf milo	18684	94	6.2	2.3	36	2.08	18.6
Dwarf kafir	24983	100	7.2	3.5	45	2.42	20.1
Blackhull kafir	17569	117	2.6	2.3	46	2.90	2.4
1915 (very wet season): ⁸							
Dwarf hegari	4201	108	19.47	7.18	52.5	3.25	43.66
Dwarf feterita	811	108	14.82	4.33	66	3.52	51.55
Improved feterita	22329	108	14.48	4.18	65	4.53	52.93
Dwarf milo	18684	115	19.36	5.24	46.5	4.37	52.60
Dwarf kafir	24983	123	8.53	4.59	60.5	5.00	65.99
Blackhull kafir	17569	133	14.84	7.17	72	5.66	58.83
Schrock kafir	1481	131	6.25	4.28	66	7.30	55.83

¹ The term fodder includes the entire plant before the seed head is removed. The yields were all obtained from duplicate twentieth-acre plats except that of Improved feterita in 1913, which was from one row 8 rods long.

² Few heads.

³ Yields of these varieties are the total from two cuttings.

⁴ The average for the growing season is based on results obtained in 1914 and 1915 except in the case of feterita No. 19517.

⁵ The results of two years; 1913 and 1914.

⁶ The yields for 1913 were all obtained from 0.03-acre plats except that of Improved feterita, which was grown in only one 8-rod row.

⁷ The yields for 1914 were all obtained from duplicate fiftieth-acre plats.

⁸ The yields for 1915 were all obtained from duplicate twentieth-acre plats.

TABLE I.—Comparative growth and yield of the new and of standard varieties of sorghum at two stations in Texas, etc.—Continued.

Place, year, and variety.	Serial No.	Season.	Row space.		Height.	Acre yield.	
			Plant.	Stalk.		Fodder.	Grain.
AT AMARILLO, TEX.—Contd.							
Average, 1913 to 1915:		<i>Days.</i>	<i>Inches.</i>	<i>Inches.</i>	<i>Inches.</i>	<i>Tons.</i>	<i>Bushels.</i>
Dwarf hegari.....	4201	96	9.16	3.89	38.5	2.64	22.89
Dwarf feterita.....	811	93	11.21	3.97	51.7	2.50	31.58
Improved feterita.....	22329	94	11.63	4.03	55.3	2.94	30.38
Dwarf milo.....	18684	102	10.52	3.81	35.5	2.49	24.42
Dwarf kafir.....	24983	111	9.68	5.16	44.5	2.62	28.70
Blackhull kafir.....	17569	123	7.31	4.02	50.7	3.30	20.41
AT HAYS, KANS.							
1914 (medium to poor season): ¹							
Dwarf hegari.....	4201	102	8.6	4.6	53	3.14	11.2
Standard feterita.....	19517	93	12.3	7	71	2.44	25.7
White milo.....	5886	90	7.6	4.3	60	2.51	31.9
Dwarf milo.....	18684	102	7.7	3.8	46	2.44	14.2
Dwarf kafir.....	24983	102	9.3	7.1	52	3.16	30.6
Blackhull kafir.....	17569	102	3.5	2.9	54	3.55	9
Schrock kafir.....	1481	102	11	7.3	47	2.26	7.5
1915 (very wet and cold season): ²							
Dwarf hegari.....	4201	107	7.3	-----	66	3.54	40.7
Dwarf feterita.....	811	107	6.3	-----	80	3.46	23.8
Improved feterita.....	22329	107	5.5	-----	84	3.51	27
White milo.....	5886	100	3.2	-----	84	4.34	42.1
Dwarf milo.....	18684	112	4.6	-----	70	4.89	40.9
Dwarf kafir.....	24983	115	7	-----	72	3.41	24.7
Blackhull kafir.....	17569	115	6.2	-----	80	4.15	12.3
Schrock kafir.....	1481	115	6.4	-----	70	3.44	8.5
Average, 1914 and 1915:							
Dwarf hegari.....	4201	105	8	-----	60	3.34	26
Feterita ³	-----	100	8.9	-----	77.5	2.98	26.4
White milo.....	5886	95	5.4	-----	72	3.48	37
Dwarf milo.....	18684	107	6.2	-----	58	3.67	27.6
Dwarf kafir.....	24983	109	8.2	-----	62	3.29	27.7
Blackhull kafir.....	17569	109	4.9	-----	67	3.85	10.7

¹ The yields given are from duplicate twentieth-acre plats.² The yields given are from duplicate 3/200-acre plats.³ The results for feterita include those for S. P. I. No. 19517 in 1914 and for S. P. I. No. 22329 in 1915.

The results shown in Table I represent fairly accurately, it is believed, the value of these varieties in the localities named. It is fortunate that the period covered by this work includes a wet year, a dry year, and one of average weather conditions.

VALUE OF THE VARIETIES IN DIFFERENT PORTIONS OF THE GREAT PLAINS.

REGION ADJACENT TO CHILLICOTHE, TEX.

In 1914 a wet fall followed a rather dry but not especially unfavorable summer, and this abundance of moisture in the fall enabled the early-maturing varieties, like feterita and Dwarf hegari, to produce second crops of grain as well as fodder. This resulted in greatly augmented yields of the three varieties of feterita, of Dwarf hegari, and also of Dwarf milo. The yield from the first cutting, which was harvested in the ordinary way with a row binder, was as follows: Dwarf hegari, 17; Dwarf feterita, 24.9; Improved feterita,

23.8; Standard feterita, 23.4; and Dwarf milo, 22.3 bushels per acre. The second cutting, produced from tillers starting at the base of the stubble, was more uniform than the first cutting, and in the Dwarf hegari and the Dwarf and Improved varieties of feterita the yield of grain was greater than that from the first cutting (fig. 4). In fields of these crops where the first crop of grain had been gathered by heading, the second crop was much less uniform and was inferior in every respect to that produced where the first cutting was made with a row binder and the plants were cut off near the ground. Additional expense is entailed, of course, in the harvesting of two crops, but the potential value of a variety must be determined from its actual production of forage and grain, together with the feeding value of the product.

It appears from the results obtained at Chillicothe that the feteritas and White milo are of most value in dry seasons and that the feterita and Dwarf hegari will under favorable conditions produce two crops in one season, while ordinary Blackhull kafir will make only one crop and in very dry seasons does not even head out. Both the new varieties of feterita, F. C. I. No. 811 and S. P. I. No. 22329, are superior to the strain now being generally grown and should be widely utilized as soon as an adequate supply of seed is available.

During the period represented by this test, Dwarf hegari ranks first, with an average yield of 31.7 bushels of grain and 3.89 tons of fodder per acre. In quality the fodder is not quite equal to that of the Blackhull kafir, but it is superior both to feterita and to milo fodder.

The White milo, although maturing quite early, lacks the required vitality or the tendency to produce tillers which is necessary for a second growth. This failure to produce two seed crops in 1914 lowered the rank of this variety in the averages. It is somewhat taller and not so leafy as the ordinary Dwarf milo, and without further improvement can hardly be expected to replace this well-known sort in the region surrounding Chillicothe. There is evidence, however, that it is capable of decided improvement by selection, both in regard to its leafiness and its dwarfness. A field of White milo much improved in both of these characters was found on the farm of Mr. W. W. Cole, near Chillicothe. This field is illustrated in figure 6. It was quite uniform in height, and in shape and size of the head resembled the ordinary Dwarf milo very closely. If it behaves similarly in future plantings, a variety of Dwarf White milo will be available similar to the Dwarf Yellow milo in everything but color of seed.

REGION ADJACENT TO AMARILLO, TEX.

Climatic conditions are more severe at Amarillo than at Chillicothe, Tex., the normal rainfall and temperature both being lower. However, the unusually good season of 1915, with its high yields, raised the averages for the period to a figure practically equaling the yields at Chillicothe. At Amarillo, *feterita*, besides showing an ability to make crops under extremely adverse conditions (fig. 5), also stands first in the averages for the three years.

It is very probable that *feterita* will continue to be grown quite extensively on the high plains of northwestern Texas, although its tendency to shatter the seed when not harvested promptly and the evident low vitality of the seed when planted in cold soil will no doubt cause most farmers to depend on ordinary Dwarf milo for their grain crop. Both the Dwarf and the Improved *feterita* proved



FIG. 6.—A field of Dwarf White milo on the farm of Mr. W. W. Cole, Chillicothe, Tex. Photographed July 24, 1914.

consistently superior to the common strain of *feterita* at Amarillo, as well as at Chillicothe.

Failure to include White milo in the 1913 and 1915 plantings prevents any fair comparison of it with the *feterita* or Dwarf milo under Amarillo conditions, but judging from the record of White milo at Hays, Kans., it may be expected to produce a good grain yield at Amarillo also.

Dwarf hegari appears to be less promising on the high plains about Amarillo than at Chillicothe, and, judging from the results obtained, it is not likely to become as popular there as near the latter point, where a considerable number of farmers are already growing it in preference to *feterita*, Dwarf milo, and Blackhull kafir.

REGION ADJACENT TO HAYS, KANS.

The season of 1913 was so severe at Hays that all the crops were practically failures. No seed yields were obtained from any of the

varieties, although Dwarf hegari and feterita made small yields of forage, as did also the Dwarf kafir. Insects completely destroyed the plantings of Dwarf milo, this variety appearing especially susceptible to the attacks of both chinch bugs and grasshoppers.

In 1914, which was an average season but with several periods of rather acute drought, feterita, White milo, and Dwarf kafir made especially good yields of grain and fair yields of fodder. The high grain yields of feterita and Dwarf kafir may have been partly due to the thin stands of these two strains, but this can not be offered as a reason for the good showing of the White milo. Dwarf hegari produced a good yield of fodder, but the seed yield was rather low.

In the season of 1915, which was very cold and wet during the spring and early summer, all the sorghums started poorly and had to be replanted. The cold weather was disastrous to feterita and retarded the growth of the kafirs to such an extent that they failed to mature fully before frost, Blackhull kafir and Schrock kafir being in the milk stage and Dwarf kafir in the soft-dough stage when frost came. Dwarf hegari, White milo, and Dwarf milo made almost equally good yields of grain, but the milos both outyielded Dwarf hegari in fodder. The quality of Dwarf hegari fodder, however, is considerably better than that of the milo, so that the advantage of the milos in this feature is more apparent than real. In the averages for the two years, White milo appears to be much the best from a grain standpoint, while Dwarf hegari, feterita, Dwarf milo, and Dwarf kafir, averaging about 10 bushels less in grain yield than the White milo, are approximately equal to it and to each other in forage yield. From these results one must conclude that the best general-purpose sorghum for this region is Dwarf kafir, since the fodder is much superior to that of the milos or feterita (fig. 7). For a purely grain sorghum, White milo deserves a more extensive trial, especially in the northwestern part of Kansas, southwestern Nebraska, and eastern Colorado. Ordinary Blackhull kafir and Schrock kafir, although more leafy and perhaps producing a better quality of fodder than Dwarf kafir, are not early enough in maturing to warrant their growth in western Kansas.

GENERAL CONCLUSIONS.

Schrock kafir has been introduced in the tabulation (Table I) merely because of the interest which has been aroused in it and to provide data to answer questions regarding its comparative value. It will be seen that its long growing season prevents it from being a success at Hays, Kans. Farther south, however, at both Chillicothe and Amarillo, Tex., it made good yields, and in 1915 it was the highest yielding sorghum at Woodward, Okla. Even with such results

it can not be recommended as the ideal dual-purpose sorghum; that is, one that will furnish high yields and a good quality of both forage and grain, because the seeds have an appreciable amount of tannin in them, and this lowers its feeding value. The presence of this tannin also adds to the evidence supporting the theory that Schrock kafir is in reality a hybrid of kafir and some sorgo, since all the sorgos, so far as at present known, have tannin in the seed. While Schrock kafir may be found to possess considerable merit as a silage sorghum, it is not likely that any variety will be generally grown because it has superior value for silage alone.

No general recommendation for all these varieties covering the whole region of the Great Plains can be made. It is quite likely that each locality will in time come to favor some particular variety

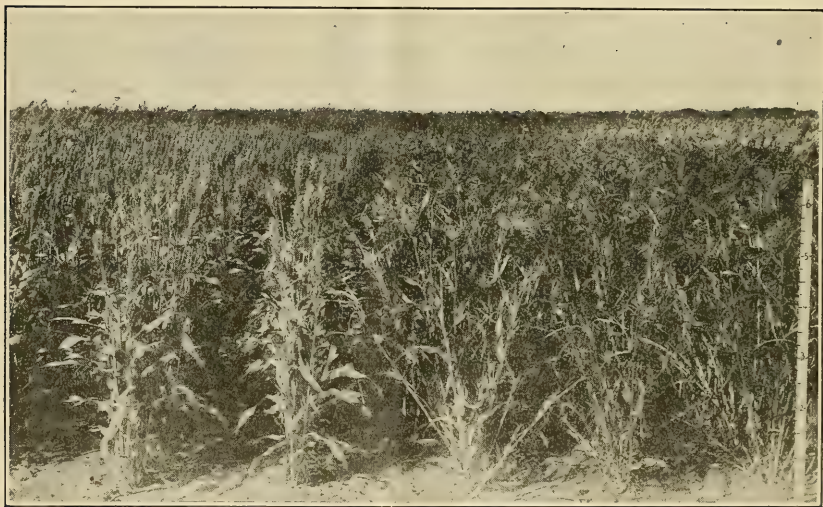


FIG. 7.—Dwarf Blackhull kafir (at the left) and Dwarf milo (at the right) at Hays, Kans., in 1915.

of sorghum, much as is now the case with corn. Dwarf hegari, Dwarf feterita, and Improved feterita have all been brought to their present standard of excellence by continued selection. Whether all or any of them will in time become established varieties in any community will depend on the impression they create on the farmers after they have been grown under actual field conditions for several years. The present publication is prepared, not for the purpose of urging their general adoption in preference to present well-known varieties, but to provide a source of information in regard to them at a time when they are being sent out for trial among farmers.

Dwarf hegari has become quite popular around Chillicothe, Tex., and can be highly recommended for the whole sorghum region in

Texas which lies south and east of the Panhandle. It also deserves a more extended trial in New Mexico, Arizona, and southern California, and through central Oklahoma and western Kansas. Several enthusiastic reports concerning Dwarf hegari have been received from southwestern Nebraska. The Nebraska branch experiment station at Curtis rates it above feterita for their conditions.

Dwarf feterita and Improved feterita should be substituted for ordinary feterita where the latter is now being grown. Feterita has shown an ability to produce crops under very low moisture conditions, and through a long series of years these two selected strains will very likely make a larger grain yield than either Dwarf milo or Dwarf kafir on the high plains of northwestern Texas, western Kansas, and eastern Colorado. The most grievous fault of feterita, that of poor germination, can perhaps be remedied by selective breeding.

White milo has made an enviable record in the matter of seed production at all of the field stations concerned in these reports. When exhibited at State and county fairs in the sorghum region it has often taken first premium in competition with the ordinary milo. The quality of fodder produced is rather inferior, but from the standpoint of grain production alone it is worthy of a much more extended planting in northwestern Texas, western Oklahoma, western Kansas, eastern Colorado, and western Nebraska.

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UNITED STATES DEPARTMENT OF AGRICULTURE



BULLETIN No. 384

Contribution from the Office of Markets and Rural
Organization,
CHARLES J. BRAND, Chief



Washington, D. C.



July 31, 1916

COSTS AND SOURCES OF FARM-MORTGAGE LOANS IN THE UNITED STATES.

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Specialist in Rural Organization.

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COSTS FOR INTEREST AND COMMISSION.

The average costs for interest and commission on farm-mortgage loans are given in Table 1. The same information is shown graphically in Diagram A. The commission figures which have been used in making up this table represent the average annual commission, or where a single advance commission is paid on a long-term loan, the equivalent annual commission. It will be seen that, in general, the average costs for interest and commission together are highest in the Southern and Rocky Mountain States, and that the lowest figures appear in the New England and Middle Atlantic States and the more highly developed agricultural sections of the corn belt. The average commissions are shown to be especially high in certain States, notably North Dakota, North Carolina, Oklahoma, and Montana.

NOTE.—The aim of this bulletin is to indicate briefly some of the results obtained from a study bearing on interest rates and commissions on farm-mortgage loans and the sources of such loans in the United States.

TABLE 1.—*Farm-mortgage loans—Average rates for interest and commission.*

Geographic division and State.	Average interest rate.	Average annual commission. ¹	Interest plus commission.	Geographic division and State.	Average interest rate.	Average annual commission. ¹	Interest plus commission.
New England:				South Atlantic—Contd.			
Maine.....	6.1	0.1	6.2	West Virginia.....	6.2	0.2	6.4
New Hampshire.....	5.3	(²)	5.3	North Carolina.....	6.3	1.4	7.7
Vermont.....	5.6	(²)	5.6	South Carolina.....	7.8	.6	8.4
Massachusetts.....	5.6	(²)	5.6	Georgia.....	7.6	1.1	8.7
Rhode Island.....	5.7	.2	5.9	Florida.....	9.0	.6	9.6
Connecticut.....	5.7	(²)	5.7	East South Central:			
Middle Atlantic:				Kentucky.....	6.7	.4	7.1
New York.....	5.5	.1	5.6	Tennessee.....	7.3	.6	7.9
New Jersey.....	5.5	.3	5.8	Alabama.....	8.7	.7	9.4
Pennsylvania.....	5.5	.3	5.8	Mississippi.....	8.0	.5	8.5
East North Central:				West South Central:			
Ohio.....	5.9	.2	6.1	Arkansas.....	9.0	.6	9.6
Indiana.....	5.8	.4	6.2	Louisiana.....	8.2	.4	8.6
Illinois.....	5.7	.3	6.0	Oklahoma.....	6.6	1.8	8.4
Michigan.....	6.3	.3	6.6	Texas.....	8.4	.6	9.0
Wisconsin.....	5.7	.1	5.8	Mountain:			
West North Central:				Montana.....	8.4	1.6	10.0
Minnesota.....	6.3	.5	6.8	Idaho.....	8.2	.7	8.9
Iowa.....	5.6	.3	5.9	Wyoming.....	9.2	.8	10.0
Missouri.....	6.2	.6	6.8	Colorado.....	8.3	.6	8.9
North Dakota.....	6.9	1.8	8.7	New Mexico.....	9.7	.8	10.5
South Dakota.....	7.0	1.0	8.0	Arizona.....	9.1	.3	9.4
Nebraska.....	6.3	.8	7.1	Utah.....	8.6	.4	9.0
Kansas.....	6.1	.8	6.9	Pacific:			
South Atlantic:				Washington.....	7.9	.8	8.7
Delaware.....	5.6	(²)	5.6	Oregon.....	7.7	.3	8.0
Maryland.....	5.7	.4	6.1	California.....	7.4	.2	7.6
Virginia.....	6.1	.7	6.8				

¹ Where the report shows a commission paid once for all in advance on a loan running more than one year, the equivalent annual commission is used.

² Less than one-tenth of 1 per cent.

Where commission is charged, it is collected either as a cash payment in advance (that is, it is taken out of the amount represented by the face of the loan) or in a number of installments. Installment commission usually is collected annually or semiannually, with the interest, but frequently arrangements are made for the payment of the whole commission on a 5-year loan, say, in two or three annual installments.

RELATIVE IMPORTANCE OF DIFFERENT RATES OF INTEREST.

Averages such as those shown in Table 1 do not indicate the range of figures which go to make up the averages. Another table (Table 2) is presented, therefore, which indicates the relative importance of different rates reported for interest plus commission in each State. This is also shown graphically in Diagram B. It will be seen that those rates which figure most prominently in the New England and corn-belt States practically disappear as one enters the cotton belt or the Rocky Mountain States.

In order to indicate still further the relative importance of the different rates reported, the data have been assembled by districts within States, following the plan of subdivision used by the Bureau of Crop Estimates as shown by the map (Plate V). Under this arrangement each State is usually divided into nine districts. Table 3 shows

the averages for interest, annual commission, and interest plus commission, by districts. It will be noted that there is considerable variation in these district averages within certain States, such as Kansas, Nebraska, Minnesota, and the Dakotas, but that there is a fair degree of uniformity in such averages in other States, for example, New York, Ohio, Indiana, and Iowa. The causes of variation will be discussed later.

TABLE 2.—*Farm-mortgage loans—Per cent distribution of replies received according to rate reported for interest plus commission.*

Geographic division and State.	Percentage of total number of replies showing, for interest plus commission, a rate ¹ of—							
	5 per cent.	6 per cent.	7 per cent.	8 per cent.	9 per cent.	10 per cent.	11 per cent.	12 per cent or over.
New England:								
Maine.....	4.2	77.1	12.5	6.2				
New Hampshire.....	75.0	25.0						
Vermont.....	26.1	73.9						
Massachusetts.....	34.6	65.4						
Rhode Island.....	33.3	50.0	16.7					
Connecticut.....	26.3	73.7						
Middle Atlantic:								
New York.....	37.9	57.6	4.0	0.5				
New Jersey.....	33.3	56.7	6.7	3.3				
Pennsylvania.....	32.1	57.2	8.9	.6			0.6	0.6
East North Central:								
Ohio.....	8.4	74.7	15.3	1.6				
Indiana.....	2.7	77.8	15.5	3.6	0.5			
Illinois.....	23.1	52.8	21.2	2.6		0.3		
Michigan.....	4.0	49.6	34.8	8.0	1.8	.9	.4	.4
Wisconsin.....	34.0	51.0	12.9	2.1				
West North Central:								
Minnesota.....	4.8	46.2	26.9	14.4	1.4	5.3		1.0
Iowa.....	13.2	76.9	9.4	.4				
Missouri.....	1.2	45.2	30.4	16.9	4.2	1.8	.3	
North Dakota.....		2.1	16.9	28.3	19.8	27.0	2.5	3.4
South Dakota.....	2.0	20.2	25.3	18.2	9.1	14.1	4.5	6.6
Nebraska.....	4.7	41.6	19.7	13.6	9.0	10.4	.7	.4
Kansas.....	1.1	43.8	36.9	10.9	2.9	3.7	.7	
South Atlantic:								
Delaware.....	37.5	62.5						
Maryland.....	8.6	74.3	14.3	2.8				
Virginia.....	1.7	52.6	29.3	12.1	.9		1.7	1.7
West Virginia.....		79.6	8.2	10.2		2.0		
North Carolina.....		40.3	22.4	15.7	6.0	6.7	2.9	6.0
South Carolina.....			6.2	63.9	20.6	5.2	2.1	2.0
Georgia.....		1.5	8.3	42.8	27.1	15.0	2.2	3.0
Florida.....				23.9	13.0	52.2	6.5	4.4
East South Central:								
Kentucky.....	.6	45.4	17.2	23.9	4.9	8.0		
Tennessee.....		18.5	20.4	32.5	8.9	18.5	.6	.6
Alabama.....		.7	2.1	32.6	16.3	31.9	5.7	10.6
Mississippi.....		8.4	7.8	45.5	13.6	20.8	1.3	2.6
West South Central:								
Arkansas.....			2.2	13.0	17.9	59.8	2.7	4.4
Louisiana.....		2.5	1.3	58.2	13.9	13.9	5.1	5.1
Oklahoma.....		2.6	14.2	43.9	15.1	22.4	.9	.9
Texas.....		1.8	6.6	34.2	18.0	29.8	6.1	3.5
Mountain:								
Montana.....			1.2	9.8	15.9	52.4	6.1	14.6
Idaho.....			4.1	35.6	34.2	19.2	5.5	1.4
Wyoming.....			2.0	17.6	11.8	49.0	9.8	9.8
Colorado.....		3.9	14.7	25.5	21.6	15.7	9.8	8.8
New Mexico.....				7.0	18.6	32.6	14.0	27.9
Arizona.....				36.4	9.1	45.4		9.1
Utah.....				33.3	26.7	40.0		
Pacific:								
Washington.....		1.2	9.9	39.5	30.9	11.1	2.5	4.9
Oregon.....		6.3	16.4	53.1	12.7	8.9	1.3	1.3
California.....		7.9	36.8	42.8	5.9	5.9		.7

¹ Rates are approximated to the nearest unit; that is, rates from 5.50 per cent to 6.49 per cent are counted as 6 per cent, etc.

TABLE 3.—*Farm-mortgage loans—Average rates for interest and commission, by States and districts.*

Geographic division, State, and district.	Average interest rate.	Average annual commission. ¹	Interest plus commission.	Geographic division, State, and district.	Average interest rate.	Average annual commission. ¹	Interest plus commission.
NEW ENGLAND.				EAST NORTH CENTRAL—contd.			
Maine.....	6.1	0.1	6.2	Wisconsin.....	5.7	0.1	5.8
New Hampshire.....	5.3	(²)	5.3	District 1.....	6.3	.2	6.5
Vermont.....	5.6	(²)	5.6	District 2.....	6.1	.2	6.3
Massachusetts.....	5.6	(²)	5.6	District 3.....	6.3	.2	6.5
Rhode Island.....	5.7	.2	5.9	District 4.....	5.8	.1	5.9
Connecticut.....	5.7	(²)	5.7	District 5.....	5.7	.1	5.8
MIDDLE ATLANTIC.				District 6.....	5.0	.1	5.1
New York.....	5.5	.1	5.6	District 7.....	5.7	(²)	5.7
District 2.....	5.4	.1	5.5	District 8.....	5.4	(²)	5.4
District 3.....	5.9	.1	6.0	District 9.....	5.0	(²)	5.0
District 4.....	5.4	.2	5.6	WEST NORTH CENTRAL.			
District 5.....	5.5	.1	5.6	Minnesota.....	6.3	.5	6.8
District 6.....	5.6	.1	5.7	District 1.....	6.7	.8	7.5
District 7.....	5.5	.1	5.6	District 2.....	8.6	1.2	9.8
District 8.....	5.5	.1	5.6	District 3.....	7.1	.8	7.9
District 9.....	5.7	.1	5.8	District 4.....	6.0	.5	6.5
New Jersey.....	5.5	.3	5.8	District 5.....	6.2	.3	6.5
Pennsylvania.....	5.5	.3	5.8	District 6.....	6.7	.8	7.5
District 1.....	5.9	.3	6.2	District 7.....	5.7	.6	6.3
District 2.....	5.7	.3	6.0	District 8.....	5.7	.2	5.9
District 3.....	5.7	(²)	5.7	District 9.....	5.8	(²)	5.8
District 4.....	6.0	.2	6.2	Iowa.....	5.6	.3	5.9
District 5.....	5.3	.4	5.7	District 1.....	5.5	.3	5.8
District 6.....	5.4	.2	5.6	District 2.....	5.4	.3	5.7
District 7.....	5.8	.4	6.2	District 3.....	5.7	.1	5.8
District 8.....	5.2	.5	5.7	District 4.....	5.5	.4	5.9
District 9.....	5.2	.1	5.3	District 5.....	5.7	.3	6.0
EAST NORTH CENTRAL.				District 6.....	5.9	.2	6.1
Ohio.....	5.9	.2	6.1	District 7.....	5.5	.5	6.0
District 1.....	5.7	.4	6.1	District 8.....	5.7	.3	6.0
District 2.....	5.9	.1	6.0	District 9.....	5.8	.2	6.0
District 3.....	5.9	.2	6.1	Missouri.....	6.2	.6	6.8
District 4.....	5.8	.3	6.1	District 1.....	5.8	.5	6.3
District 5.....	5.8	.4	6.2	District 2.....	5.8	.6	6.4
District 6.....	5.7	.1	5.8	District 3.....	5.9	.5	6.4
District 7.....	6.0	.3	6.3	District 4.....	5.9	.5	6.4
District 8.....	6.1	.2	6.3	District 5.....	6.5	.6	7.1
District 9.....	6.0	(²)	6.0	District 6.....	6.5	.3	6.9
Indiana.....	5.8	.4	6.2	District 7.....	6.3	.8	7.1
District 1.....	5.5	.4	5.9	District 8.....	7.1	.9	8.0
District 2.....	6.0	.4	6.4	District 9.....	6.6	.6	7.2
District 3.....	5.7	.4	6.1	North Dakota.....	6.9	1.8	8.7
District 4.....	5.8	.4	6.2	District 1.....	6.8	2.2	9.0
District 5.....	5.8	.5	6.3	District 2.....	6.7	1.9	8.6
District 6.....	5.7	.4	6.1	District 3.....	6.3	1.3	7.6
District 7.....	6.0	.3	6.3	District 4.....	7.7	2.4	10.1
District 8.....	6.3	.1	6.4	District 5.....	6.8	1.4	8.2
District 9.....	5.8	.3	6.1	District 6.....	6.4	1.0	7.4
Illinois.....	5.7	.3	6.0	District 7.....	7.3	2.8	10.1
District 1.....	5.6	.2	5.8	District 8.....	7.8	1.8	9.6
District 2.....	5.3	.2	5.5	District 9.....	6.5	1.2	7.7
District 3.....	5.7	.2	5.9	South Dakota.....	7.0	1.0	8.0
District 4.....	5.8	.2	6.0	District 1.....	9.0	1.8	10.8
District 5.....	5.7	.3	6.0	District 2.....	6.5	.9	7.4
District 6.....	5.4	.3	5.7	District 3.....	6.3	.7	7.0
District 6a.....	5.9	.5	6.4	District 4.....	8.3	1.4	9.7
District 7.....	6.1	.3	6.4	District 5.....	6.5	.9	7.4
District 8.....	6.4	.5	6.9	District 6.....	5.8	.5	6.3
District 9.....	6.3	.3	6.6	District 7.....	7.5	1.9	9.4
Michigan.....	6.3	.3	6.6	District 8.....	7.2	1.4	8.6
District 1.....	6.9	.8	7.7	District 9.....	6.0	.6	6.6
District 2.....	6.7	.6	7.3	Nebraska.....	6.3	.8	7.1
District 3.....	6.9	1.4	8.3	District 1.....	7.8	1.0	8.8
District 4.....	6.7	.5	7.2	District 2.....	6.8	1.2	8.0
District 5.....	6.6	.4	7.0	District 3.....	5.6	.6	6.2
District 6.....	6.5	.2	6.7	District 4.....	7.1	1.6	8.7
District 7.....	6.2	.2	6.4	District 5.....	5.9	.7	6.6
District 8.....	5.9	.1	6.0	District 6.....	5.6	.5	6.1
District 9.....	5.8	.1	5.9	District 7.....	7.4	1.3	8.7

¹ Where the report shows a commission paid once for all in advance on a loan running more than one year, the equivalent annual commission is used.

² Less than one-tenth of 1 per cent.

TABLE 3.—*Farm-mortgage loans—Average rates for interest and commission, by States and districts—Continued.*

Geographic division, State, and district.	Average interest rate.	Average annual commission. ¹	Interest plus commission.	Geographic division, State, and district.	Average interest rate.	Average annual commission. ¹	Interest plus commission.
WEST NORTH CENTRAL—continued.				EAST SOUTH CENTRAL.			
Nebraska—Contd.				Kentucky.....	6.7	0.4	7.1
District 8.....	6.1	0.6	6.7	District 1.....	6.9	.4	7.3
District 9.....	5.7	.5	6.2	District 2.....	6.4	.1	6.5
Kansas.....	6.1	.8	6.9	District 3.....	6.7	.4	7.1
District 1.....	7.7	1.1	8.8	District 5.....	6.0	.3	6.3
District 2.....	6.0	.7	6.7	District 6.....	7.0	.4	7.4
District 3.....	5.7	.6	6.3	District 7.....	7.8	.2	8.0
District 4.....	8.0	.8	8.8	District 7a.....	6.7	.4	7.1
District 5.....	5.9	.7	6.6	District 8.....	6.5	.5	7.0
District 6.....	5.7	.8	6.5	District 9.....	7.4	.4	7.8
District 7.....	7.3	1.5	8.8	Tennessee.....	7.3	.6	7.9
District 8.....	6.1	.8	6.9	District 1.....	8.0	.5	8.5
District 9.....	5.8	.7	6.5	District 2.....	6.8	.9	7.7
SOUTH ATLANTIC.				District 3.....	6.3	.5	6.8
Delaware.....	5.6	(²)	5.6	District 4.....	8.4	.5	8.9
Maryland.....	5.7	.4	6.1	District 5.....	6.8	.6	7.4
District 1.....	5.7	.5	6.2	District 6.....	6.8	.5	7.3
District 2.....	5.6	.3	5.9	District 7.....	8.6	.6	9.2
District 3.....	5.8	.5	6.3	District 8.....	6.8	.6	7.4
District 5.....	5.9	.3	6.2	District 9.....	7.3	.4	7.7
District 6.....	(³)	(³)	(³)	Alabama.....	8.7	.7	9.4
District 8.....	6.0	.3	6.3	District 1.....	8.8	.3	9.1
Virginia.....	6.1	.7	6.8	District 2.....	9.0	.9	9.9
District 2.....	5.8	.6	6.4	District 3.....	8.7	.7	9.4
District 4.....	5.9	.6	6.5	District 4.....	9.0	.5	9.5
District 5.....	6.2	1.5	7.7	District 5.....	8.2	.9	9.1
District 6.....	6.1	.5	6.6	District 6.....	9.4	.4	9.8
District 7.....	6.1	.3	6.4	District 7.....	8.2	.9	9.1
District 8.....	6.4	.4	6.8	District 8.....	9.0	.3	9.3
District 9.....	6.5	.3	6.8	District 9.....	8.7	.9	9.6
West Virginia.....	6.2	.2	6.4	Mississippi.....	8.0	.5	8.5
District 1.....	6.1	.1	6.2	District 1.....	7.6	1.3	8.9
District 2.....	6.0	.1	6.1	District 2.....	8.2	.2	8.4
District 3.....	6.0	.4	6.4	District 3.....	8.3	.4	8.7
District 4.....	7.5	.2	7.7	District 4.....	7.8	.6	8.4
District 5.....	6.3	(²)	6.3	District 5.....	8.0	.5	8.5
District 6.....	6.0	.2	6.2	District 6.....	7.5	.5	8.0
District 8.....	6.1	.1	6.2	District 7.....	8.2	.5	8.7
North Carolina.....	6.3	1.4	7.7	District 8.....	8.3	.6	8.9
District 1.....	6.1	1.6	7.7	District 9.....	7.7	.5	8.2
District 2.....	6.0	1.2	7.2	WEST SOUTH CENTRAL.			
District 3.....	5.9	.7	6.6	Arkansas.....	9.0	.6	9.6
District 4.....	6.3	1.1	7.4	District 1.....	8.6	.8	9.4
District 5.....	6.2	1.5	7.7	District 2.....	9.2	.6	9.8
District 6.....	6.9	2.1	9.0	District 3.....	8.9	.5	9.4
District 7.....	6.9	1.8	8.7	District 4.....	9.1	.7	9.8
District 8.....	6.1	1.0	7.1	District 5.....	9.2	.5	9.7
District 9.....	6.4	1.4	7.8	District 6.....	8.8	.5	9.3
South Carolina.....	7.8	.6	8.4	District 7.....	8.9	1.2	10.1
District 1.....	7.8	.5	8.3	District 8.....	10.0	(²)	10.0
District 2.....	7.9	.4	8.3	District 9.....	8.5	.7	9.2
District 3.....	7.6	.4	8.0	Louisiana.....	8.2	.4	8.6
District 4.....	7.7	.7	8.4	District 1.....	8.3	.3	8.6
District 5.....	7.9	.5	8.4	District 2.....	9.2	.6	9.8
District 6.....	(³)	(³)	(³)	District 3.....	7.8	.2	8.0
District 8.....	7.8	1.1	8.9	District 4.....	8.3	.5	8.8
Georgia.....	7.6	1.1	8.7	District 5.....	8.4	.3	8.7
District 1.....	7.3	.7	8.0	District 6.....	8.3	.5	8.8
District 2.....	7.6	1.1	8.7	District 7.....	8.2	.9	9.1
District 3.....	7.4	1.0	8.4	District 8.....	7.6	.4	8.0
District 4.....	7.7	1.1	8.8	District 9.....	7.6	.2	7.8
District 5.....	7.5	1.3	8.8	Oklahoma.....	6.6	1.8	8.4
District 6.....	7.1	1.4	8.5	District 1.....	6.6	1.6	8.2
District 7.....	7.9	1.1	9.0	District 2.....	6.0	1.2	7.2
District 8.....	7.3	1.3	8.6	District 3.....	7.2	1.8	9.0
District 9.....	7.6	.6	8.2	District 4.....	6.5	1.7	8.2
Florida.....	9.0	.6	9.6	District 5.....	6.6	1.5	8.1
District 1.....	9.0	.7	9.7	District 6.....	7.2	2.2	9.4
District 3.....	9.7	.2	9.9	District 7.....	6.3	1.6	7.9
District 5.....	8.5	1.0	9.5				
District 8.....	9.1	.3	9.4				

¹ Where the report shows a commission paid once for all in advance on a loan running more than one year, the equivalent annual commission is used.

² Less than one-tenth of 1 per cent.

³ Data at hand not sufficient to warrant the showing of a district average.

TABLE 3.—*Farm-mortgage loans—Average rates for interest and commission, by States and districts—Continued.*

Geographic division, State, and district.	Average interest rate.	Average annual commission. ¹	Interest plus commission.	Geographic division, State, and district.	Average interest rate.	Average annual commission. ¹	Interest plus commission.
WEST SOUTH CENTRAL—continued.				MOUNTAIN—contd.			
Oklahoma—Contd.				Colorado.....	8.3	0.6	8.9
District 8.....	6.6	2.1	8.7	District 1.....	8.0	.5	8.5
District 9.....	7.1	2.8	9.6	District 2.....	7.2	.4	7.6
Texas.....	8.4	.6	9.0	District 3.....	8.4	.7	9.1
District 1.....	8.6	.9	9.5	District 4.....	8.0	.5	8.5
District 2.....	8.2	.6	8.8	District 5.....	7.8	.6	8.4
District 3.....	9.6	.3	9.9	District 6.....	9.5	.8	10.3
District 4.....	(²)	(²)	(²)	District 7.....	8.8	.5	9.3
District 4a.....	8.3	.5	8.8	District 8.....	8.0	.9	8.9
District 5.....	7.9	.6	8.5	District 9.....	7.9	.5	8.4
District 6.....	9.0	.9	9.9	New Mexico.....	9.7	.8	10.5
District 8.....	8.2	.8	9.0	Arizona.....	9.1	.3	9.4
District 9.....	8.4	.6	9.0	Utah.....	8.6	.4	9.0
MOUNTAIN.				PACIFIC.			
Montana.....	8.4	1.6	10.0	Washington.....	7.9	.8	8.7
District 1.....	8.1	1.9	10.0	District 1.....	7.9	.5	8.4
District 2.....	8.7	1.8	10.5	District 2.....	9.1	1.7	10.8
District 3.....	8.5	1.7	10.2	District 3.....	8.9	.6	9.5
District 4.....	(²)	(²)	(²)	District 4.....	7.9	.9	8.8
District 5.....	8.2	1.5	9.7	District 5.....	8.3	.8	9.1
District 6.....	8.5	2.4	10.9	District 6.....	7.3	.5	7.8
District 7.....	(²)	(²)	(²)	District 7.....	7.7	.9	8.6
District 8.....	8.1	1.1	9.2	District 8.....	7.8	.8	8.6
District 9.....	8.7	1.3	10.0	District 9.....	7.6	.3	7.9
Idaho.....	8.2	.7	8.9	Oregon.....	7.7	.3	8.0
District 1.....	7.9	.5	8.4	District 1.....	7.5	.3	7.8
District 2.....	(²)	(²)	(²)	District 2.....	7.8	.3	8.1
District 4.....	8.5	.5	9.0	District 3.....	7.7	.3	8.0
District 5.....	8.0	.9	8.9	District 4.....	7.4	.4	7.8
District 7.....	8.3	.6	8.9	District 5.....	8.1	.5	8.6
District 8.....	8.5	.6	9.1	District 7.....	7.9	.2	8.1
District 9.....	8.3	.9	9.2	District 8.....	(²)	(²)	(²)
Wyoming.....	9.2	.8	10.0	District 9.....	(²)	(²)	(²)
District 1.....	9.4	.7	10.1	California.....	7.4	.2	7.6
District 2.....	9.8	.3	10.1	District 1.....	6.4	.1	6.5
District 3.....	10.1	1.5	11.6	District 2.....	8.2	.2	8.4
District 4.....	9.3	.7	10.0	District 3.....	7.4	(³)	7.4
District 5.....	8.8	.5	9.3	District 4.....	7.2	.1	7.3
District 6.....	8.7	1.3	10.0	District 5.....	7.0	.2	7.2
District 7.....	(²)	(²)	(²)	District 5a.....	7.7	.3	8.0
District 8.....	(²)	(²)	(²)	District 6.....	7.8	.1	7.9
District 9.....	8.5	.9	9.4	District 6a.....	7.7	.2	7.9
				District 8.....	7.5	.4	7.9

¹ Where the report shows a commission paid once for all in advance on a loan running more than one year, the equivalent annual commission is used.

² Data at hand not sufficient to warrant the showing of a district average.

³ Less than one-tenth of 1 per cent.

PERCENTAGE OF BUSINESS ON WHICH COMMISSION IS PAID.

Table 4 and Diagram C reflect the relative importance of farm-mortgage loans with no commission, advance commission, and annual commission in each State, as indicated by these studies. It will be noticed that in those States where the margin charged for commission is relatively high—for example, North Dakota, Oklahoma, and Montana—the percentage of loans on which commission is charged is also relatively high. Obviously, the general average for commission is affected both by the amount of the commission where this is charged, as well as by the relative number of loans which pay commission.

There is a fairly definite relation between the proportion of the farm-mortgage loans in a given State which are made with commission and without commission, and the important sources from which funds are obtained for such loans. Broadly speaking, the no-commission loans represent that part of the farm-mortgage loans made from local capital. To the extent therefore that the farm-mortgage loans made by banks indicate the relative amount of local capital thus invested one may expect to find some degree of correlation between the proportion of no-commission loans and the proportion of the total amount of farm mortgages held by the local banks. In Arkansas, for example, where the figures show that more than one-fourth of the total farm-mortgage loans are made by banks, 67 per cent of the farm-mortgage business is done without commission, while in Oklahoma, where the farm mortgages held by local banks represent only 3 per cent of the estimated total outstanding, less than 9 per cent of the business is done without commission.

TABLE 4.—Percentage of farm-mortgage business on which commission is paid.

Geographic division and State.	Percentage without commission.	Percentage with commission.		
		Total.	With commission paid in advance.	With commission paid in installments.
New England:				
Maine.....	91.1	8.9	5.0	3.9
New Hampshire.....	96.6	3.4	3.4	.....
Vermont.....	94.1	5.9	4.8	1.1
Massachusetts.....	97.2	2.8	2.7	.1
Rhode Island.....	78.3	21.7	11.7	10.0
Connecticut.....	98.7	1.3	1.3	.....
Middle Atlantic:				
New York.....	86.6	13.4	9.6	3.8
New Jersey.....	72.3	27.7	18.7	9.0
Pennsylvania.....	81.4	18.6	10.1	8.5
East North Central:				
Ohio.....	73.7	26.3	17.9	8.4
Indiana.....	54.5	45.5	36.2	9.3
Illinois.....	52.7	47.3	39.1	8.2
Michigan.....	76.8	23.2	18.0	5.2
Wisconsin.....	85.1	14.9	10.4	4.5
West North Central:				
Minnesota.....	52.3	47.7	20.0	27.7
Iowa.....	36.0	64.0	51.3	12.7
Missouri.....	45.1	54.9	28.0	26.9
North Dakota.....	20.2	79.8	17.0	62.8
South Dakota.....	31.8	68.2	45.5	22.7
Nebraska.....	30.7	69.3	53.5	15.8
Kansas.....	32.2	67.8	30.6	37.2
South Atlantic:				
Delaware.....	98.1	1.9	1.9	.....
Maryland.....	64.3	35.7	28.5	7.2
Virginia.....	65.9	34.1	26.2	7.9
West Virginia.....	88.9	11.1	8.8	2.3
North Carolina.....	59.1	40.9	27.5	13.4
South Carolina.....	64.7	35.3	26.0	9.3
Georgia.....	33.9	66.1	54.1	12.0
Florida.....	70.2	29.8	18.6	11.2
East South Central:				
Kentucky.....	76.7	23.3	14.2	9.1
Tennessee.....	64.6	35.4	23.9	11.5
Alabama.....	62.8	37.2	25.2	12.0
Mississippi.....	74.5	25.5	15.7	9.8

TABLE 4.—*Percentage of farm-mortgage business on which commission is paid—*
Continued.

Geographic division and State.	Percent- age without commis- sion.	Percentage with commis- sion.		
		Total.	With commis- sion paid in advance.	With commis- sion paid in install- ments.
West South Central:				
Arkansas.....	66.9	33.1	18.6	14.5
Louisiana.....	76.8	23.2	16.3	6.9
Oklahoma.....	8.4	91.6	36.7	54.9
Texas.....	57.0	43.0	27.1	15.9
Mountain:				
Montana.....	31.1	68.9	28.4	40.5
Idaho.....	35.8	64.2	45.6	18.6
Wyoming.....	59.9	40.1	28.1	12.0
Colorado.....	41.7	58.3	47.0	11.3
New Mexico.....	59.0	41.0	32.8	8.2
Arizona.....	80.5	19.5	9.5	10.0
Utah.....	67.0	33.0	18.3	14.7
Pacific:				
Washington.....	41.8	58.2	46.4	11.8
Oregon.....	68.4	31.6	23.6	8.0
California.....	81.0	19.0	15.1	3.9

Again, it is found that the States deriving a large percentage of their farm-mortgage funds from insurance companies are among those where commission is paid on a relatively large proportion of the farm-mortgage loans. This condition follows naturally from the fact that wherever capital for mortgage loans is obtained from outside sources, especially from distant sources, it generally passes through the hands of one or more middlemen, to whom commissions must be paid. Insurance companies, of course, represent only one of several outside sources from which capital for farm-mortgage loans is secured, but they are of sufficient importance in a number of States to make it of interest to compare the proportion of the total farm-mortgage capital which they furnish with the proportion of farm-mortgage business on which commission is charged. For example, in Georgia, Nebraska, Oklahoma, Kansas, South Dakota, and Iowa, which are among the States obtaining the largest proportion of their farm-mortgage capital from insurance companies, the percentage of farm-mortgage business on which commission is charged ranges from 64 (in Iowa) to 92 (in Oklahoma). On the other hand, in States like Michigan and Wisconsin, where farm mortgages held by insurance companies represent less than 2 per cent of the estimated total farm-mortgage debt, the proportion of the farm-mortgage business on which commission is paid is much less, and those Eastern States where the insurance companies do practically no farm-mortgage business are among those having the lowest percentage of commission loans.

It may be concluded, therefore, that the practice of charging commission is most widely current in States where it is necessary to

DIAGRAM A. FARM MORTGAGE LOANS
AVERAGE RATES FOR INTEREST AND COMMISSION

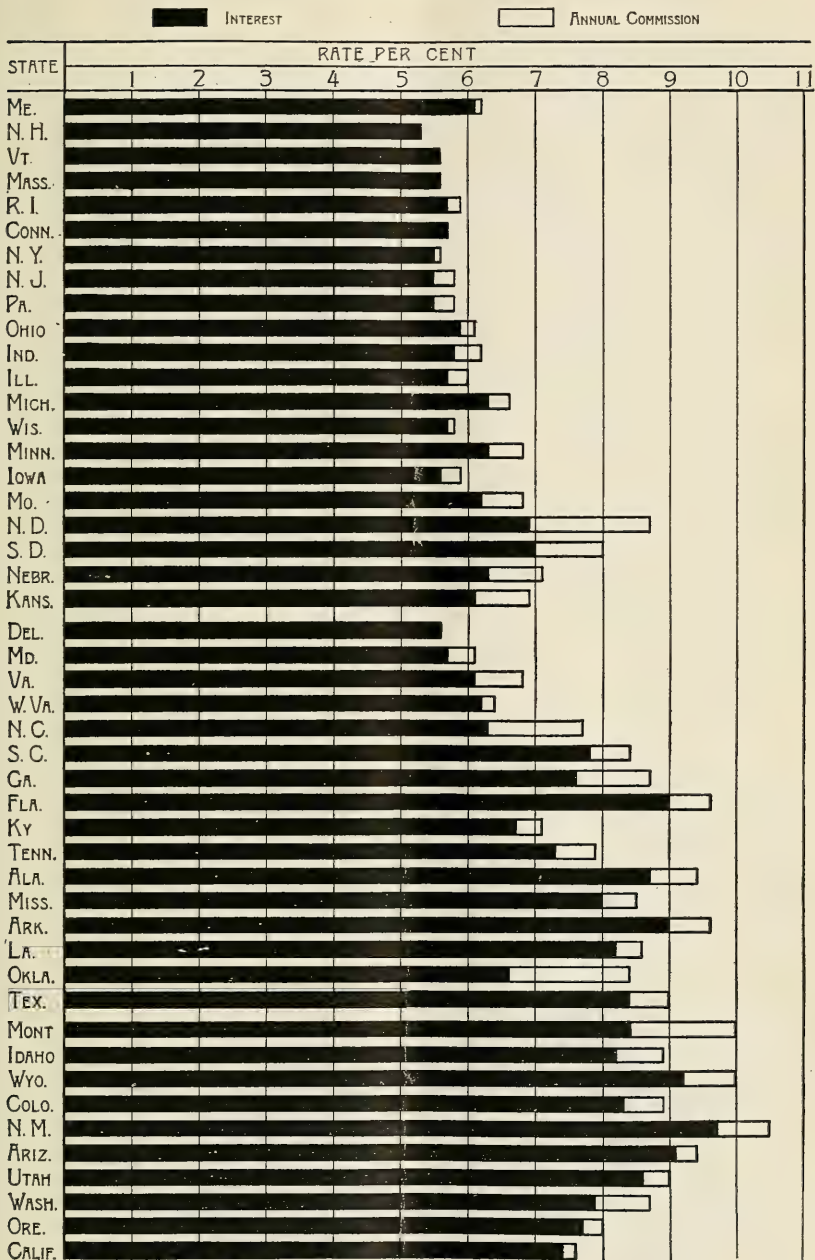


DIAGRAM B. FARM MORTGAGE LOANS
RATES REPORTED FOR INTEREST PLUS COMMISSION

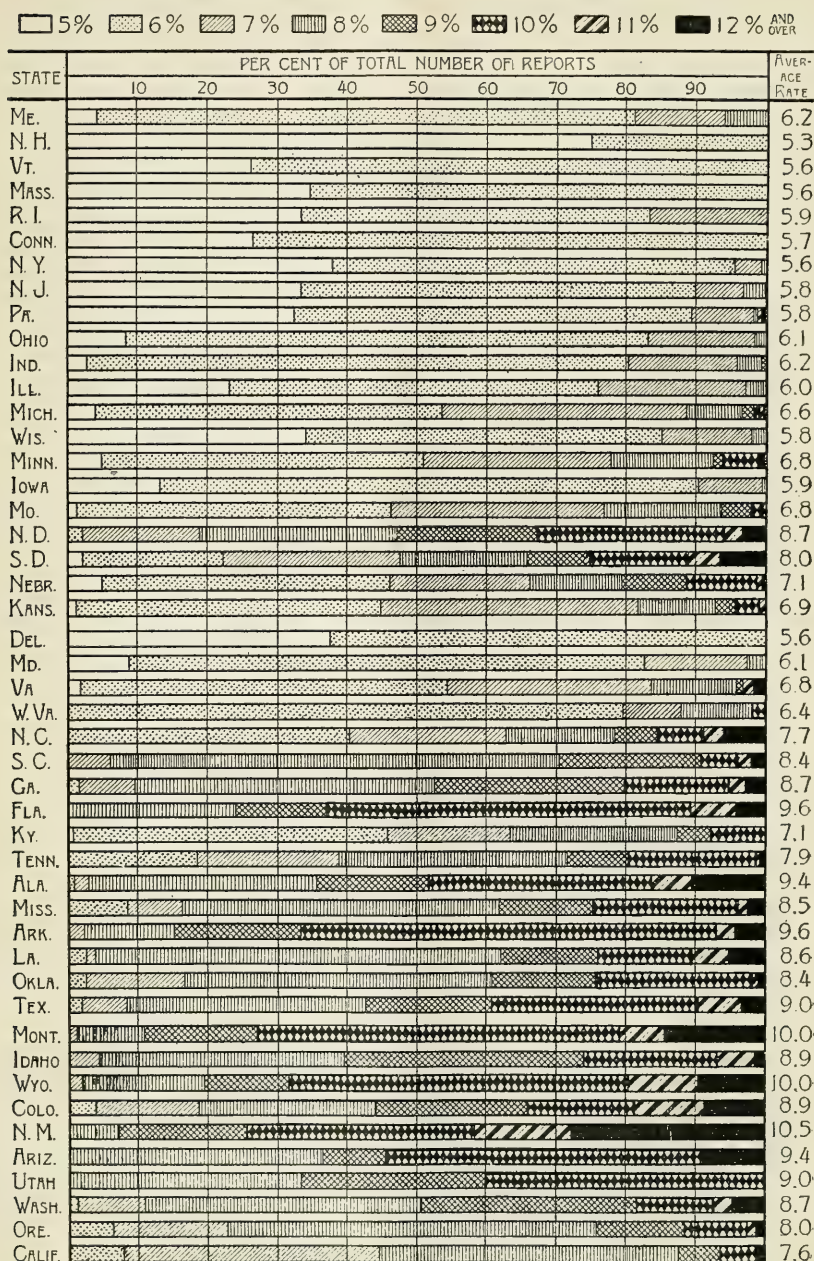


DIAGRAM C. FARM MORTGAGE LOANS PERCENTAGE OF BUSINESS ON WHICH COMMISSION IS PAID

INSTALLMENT COMMISSION
 ADVANCE COMMISSION
 NO COMMISSION

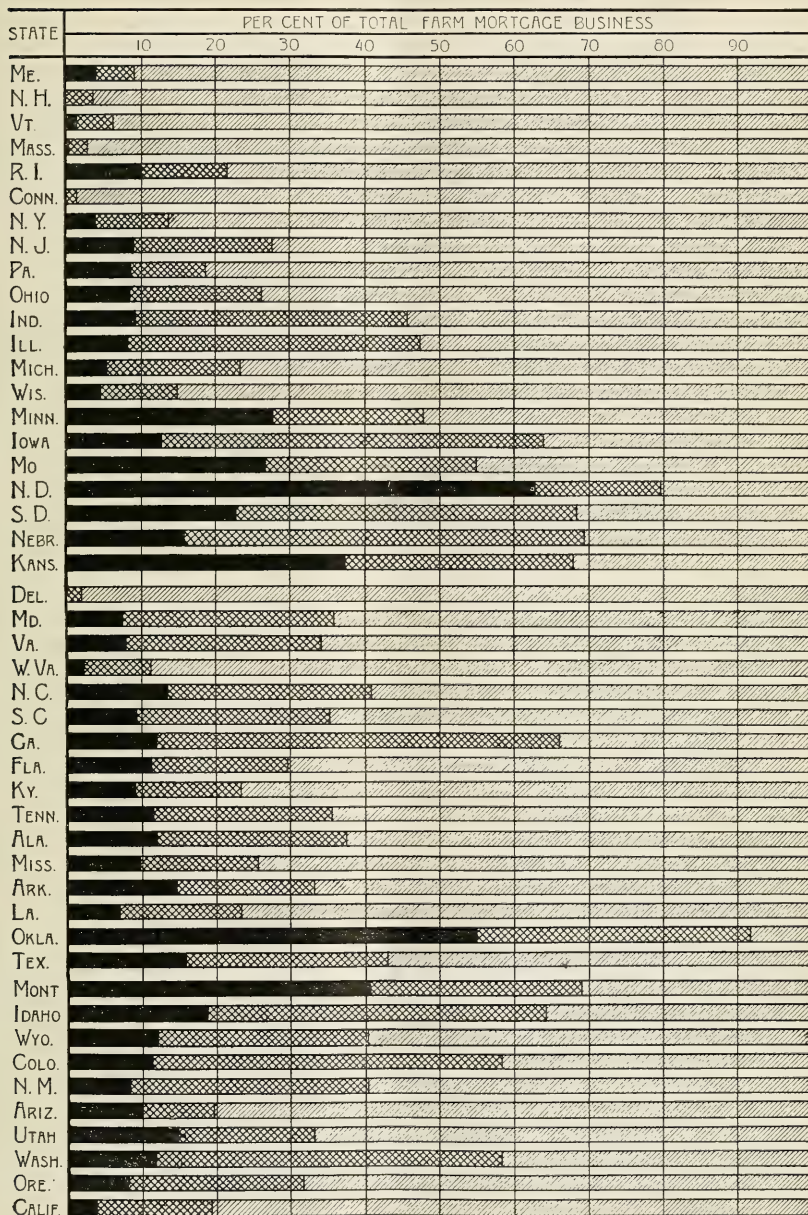


DIAGRAM D. FARM MORTGAGES HELD
BY LIFE INSURANCE COMPANIES AND BANKS AND
TOTAL FARM MORTGAGE DEBT

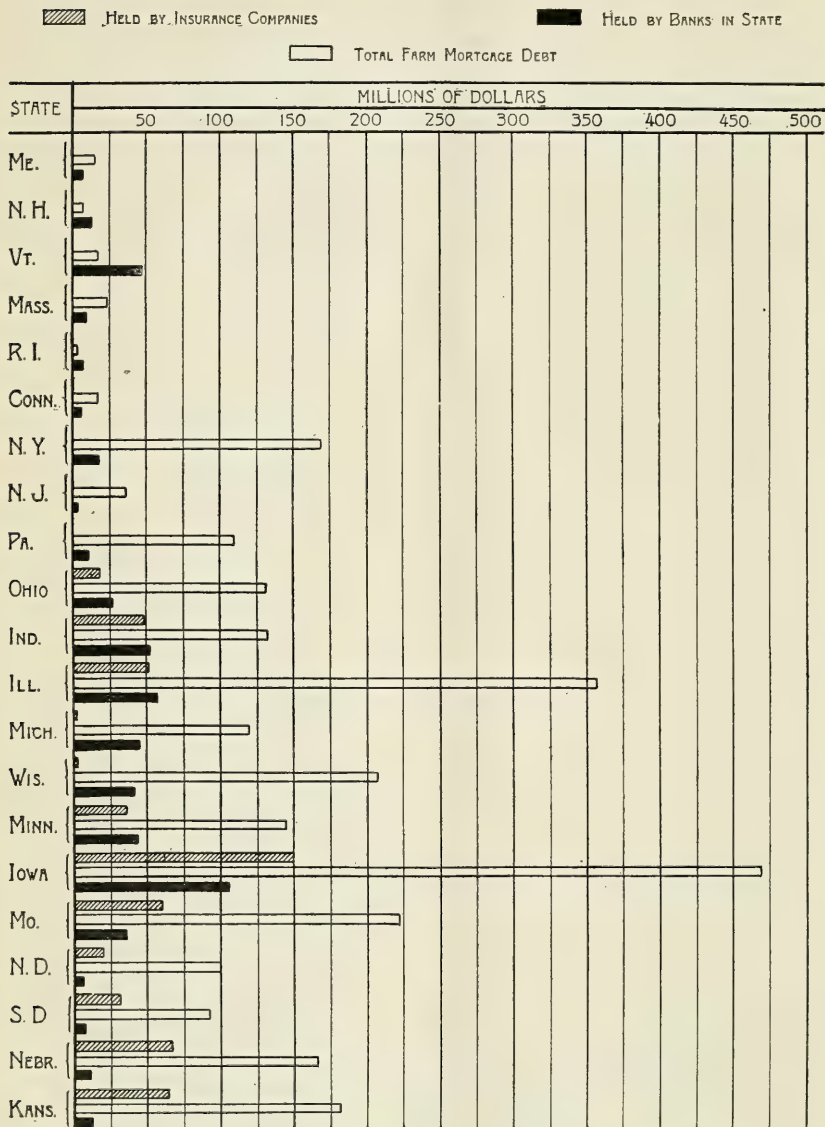
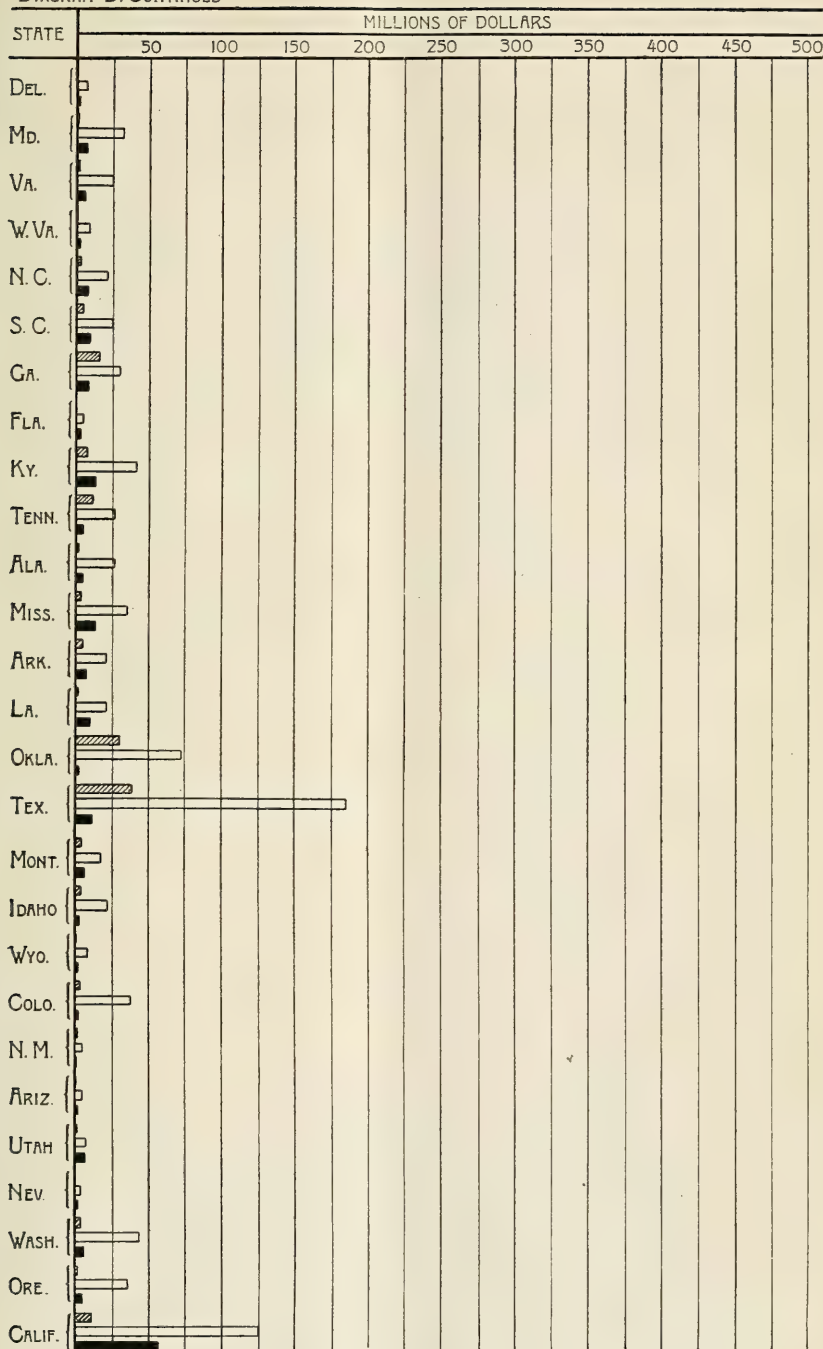


DIAGRAM 'D. CONTINUED



MAP OF THE UNITED STATES SHOWING DISTRICTS USED IN TABLE 3



draw on outside capital for considerable amounts; and that, on the other hand, in States where local capital is in the main sufficient for farm-mortgage loans, a large proportion of the loans are made without the payment of any commission.

SOURCES OF CAPITAL FOR FARM-MORTGAGE LOANS.

BANKS.

The sources of capital available for farm-mortgage loans in the various States have been studied carefully. Banks appear to furnish from their own funds approximately \$740,000,000, or more than one-fifth of the total amount invested in farm mortgages in the United States. Table 5 and Diagram D show the relative importance of the farm mortgages held by banks in each State. In California the farm mortgages held by banks represent 45 per cent of the estimated total farm-mortgage debt; in Louisiana, 45 per cent; in Indiana and Michigan, nearly 40 per cent; and in Mississippi and South Carolina, more than 36 per cent.

So far as the bank funds in any State invested in farm mortgages represent local capital, there is the advantage of first-hand contact with borrowers, enabling the investor to see that the security is properly cared for during the term of the loan. In certain sections, such as the New England and the Middle Atlantic States, where it is customary for banks to place loans in other States, the banks do not have this advantage, but must operate through other agencies in placing their loans.

TABLE 5.—*Quantitative data relative to farm-mortgage loans.*

[Figures for amounts represent thousands of dollars.]

Geographic division and State.	Estimated total farm-mortgage debt. ¹	Farm mortgages held by life insurance companies. ²		Farm mortgages held by banks. ³		Farm mortgages "handled" by banks. ⁴
		Amount.	Per cent of estimated total.	Amount.	Per cent of estimated total.	
United States.....	3,598,985	693,940	19.3	739,500	20.6	486,580
Geographic divisions:						
New England.....	80,544	106	0.1	84,900	105.4	10
Middle Atlantic.....	313,150	556	.2	30,900	9.9	2,040
East North Central.....	944,436	121,075	12.8	220,000	23.3	123,360
West North Central.....	1,375,903	426,960	31.0	216,400	15.7	282,710
South Atlantic.....	153,155	22,930	15.0	40,800	26.6	19,920
East South Central.....	127,135	22,871	18.0	33,600	26.4	4,710
West South Central.....	299,614	72,685	24.3	27,900	9.3	18,750
Mountain.....	101,285	12,532	12.4	19,800	19.5	17,300
Pacific.....	203,757	14,225	7.0	65,200	32.0	17,780

¹ Estimate based on Thirteenth Census figures, assuming that the ratio between the mortgage debt on farms operated by their owners and the total value of all such farms holds good for tenant farms also. It is possible that this ratio may be too high for the tenant farms in some of the States, in which case the estimates will be too large; but even if this is the case, the figures presented have considerable value as representing the maximum amount of farm mortgages probably outstanding in the census year.

² Based on reports received (in October, 1915) from 2-0 insurance companies, comprising five-sixths of the total number in the United States and having more than 99 per cent of the total admitted assets.

³ Estimate based on reports received from banks in the spring of 1914.

⁴ Farm mortgages negotiated by banks or bank officials as agents or correspondents for other investors. Estimates based on reports received from banks in the spring of 1914.

TABLE 5.—Quantitative data relative to farm-mortgage loans—Continued.

[Figures for amounts represent thousands of dollars.]

Geographic division and State.	Estimated total farm-mortgage debt. ¹	Farm mortgages held by life insurance companies. ²		Farm mortgages held by banks. ³		Farm mortgages "handled" by banks. ⁴
		Amount.	Per cent of estimated total.	Amount.	Per cent of estimated total.	
New England:						
Maine.....	13,727	15	0.1	6,000	43.7	.....
New Hampshire.....	6,100	.....	.....	12,500	204.9	.....
Vermont.....	17,113	13	.1	46,700	272.9	.....
Massachusetts.....	24,077	9	(⁵)	8,700	36.2	10
Rhode Island.....	2,514	.....	.....	6,000	238.7	.....
Connecticut.....	17,013	69	.4	5,000	29.4	.....
Middle Atlantic:						
New York.....	168,234	128	.1	18,200	10.8	1,150
New Jersey.....	35,610	222	.6	2,600	7.3	30
Pennsylvania.....	109,312	206	.2	10,100	9.2	860
East North Central:						
Ohio.....	130,678	17,073	13.1	26,200	20.1	1,360
Indiana.....	132,325	48,789	36.9	52,000	39.3	14,590
Illinois.....	355,802	51,046	14.3	56,200	15.8	87,530
Michigan.....	118,950	1,706	1.4	44,900	37.8	6,640
Wisconsin.....	206,681	2,461	1.2	40,700	19.7	13,240
West North Central:						
Minnesota.....	145,181	35,577	24.5	43,600	30.0	43,020
Iowa.....	469,063	150,150	32.0	104,800	22.3	70,230
Missouri.....	223,107	59,699	26.8	34,900	15.6	31,170
North Dakota.....	100,364	19,423	19.4	5,000	5.0	42,370
South Dakota.....	92,467	31,024	33.6	6,200	6.7	43,190
Nebraska.....	165,015	66,614	40.4	10,400	6.3	19,580
Kansas.....	180,706	64,473	35.7	11,500	6.4	33,150
South Atlantic:						
Delaware.....	6,857	46	.7	1,600	23.3	.....
Maryland.....	32,393	492	1.5	6,000	18.5	310
Virginia.....	25,007	670	2.7	5,000	20.0	570
West Virginia.....	8,725	23	.3	1,700	19.5	30
North Carolina.....	21,005	2,267	10.8	6,900	32.9	2,200
South Carolina.....	21,967	3,884	15.6	9,000	36.1	3,180
Georgia.....	29,711	15,479	52.1	8,000	26.9	12,280
Florida.....	4,490	69	1.5	2,600	57.9	1,350
East South Central:						
Kentucky.....	41,305	7,170	17.4	13,300	32.2	2,580
Tennessee.....	25,468	10,674	41.9	4,000	15.7	840
Alabama.....	25,943	1,771	6.8	3,700	14.3	750
Mississippi.....	34,419	3,256	9.5	12,600	36.6	540
West South Central:						
Arkansas.....	21,023	4,259	20.3	5,700	27.1	1,250
Louisiana.....	21,141	1,500	7.1	9,000	42.6	2,610
Oklahoma.....	73,129	29,065	39.7	2,100	2.9	6,550
Texas.....	184,321	37,861	20.5	11,100	6.0	8,340
Mountain:						
Montana.....	17,111	3,518	20.6	5,200	30.4	7,850
Idaho.....	21,566	2,948	13.7	2,200	10.2	4,980
Wyoming.....	7,148	487	6.8	1,200	16.8	830
Colorado.....	36,767	3,135	8.5	2,100	5.7	1,740
New Mexico.....	4,555	1,191	26.0	400	8.7	390
Arizona.....	4,161	376	9.0	1,600	38.5	1,070
Utah.....	6,818	862	12.6	6,000	88.0	340
Nevada.....	3,129	15	.5	1,100	35.2	100
Pacific:						
Washington.....	43,470	3,087	7.1	5,000	11.5	11,110
Oregon.....	35,535	1,091	3.1	4,100	11.5	2,910
California.....	124,752	10,047	8.1	56,100	45.0	3,760

¹ See footnote 1 on page 9.² See footnote 2 on page 9.³ See footnote 3 on page 9.⁴ See footnote 4 on page 9.⁵ Less than one-tenth of 1 per cent.

The relative importance of farm-mortgage loans from different classes of banks may also be noted. In Iowa, where 56 per cent of the total number of stock savings banks of the United States are located, banks of this class supply more than two-thirds of the

total capital from all banks in the State. Likewise in California the savings banks furnish even a larger proportion of the total capital invested in farm mortgages by all banks. On the other hand, in Minnesota, where there are few savings banks, the farm-mortgage loans held by State and private banks and trust companies constitute about 95 per cent of the total amount of such loans held by all banks in that State.

LIFE INSURANCE COMPANIES.

The importance of life insurance companies as sources of capital for farm-mortgage loans in the various States is also shown in Table 5 and in Diagram D. It is seen that these insurance companies supply approximately \$700,000,000 for farm-mortgage loans, or about one-fifth of the total farm-mortgage capital of the United States. Practically one-half of the insurance money is invested in the four States of Iowa, Missouri, Kansas, and Nebraska. Iowa alone holds nearly 22 per cent of the total amount of insurance money invested in farm mortgages. In few of the Southern or Rocky Mountain States do the insurance funds invested in farm mortgages represent more than one-half of 1 per cent of the total farm-mortgage capital obtained from this source.

The life insurance companies either have their own farm-mortgage departments, through which they receive and pass on applications for loans, or they purchase farm mortgages outright in the commercial market. The latter practice generally is limited to the smaller insurance companies, the volume of whose business in this field is not sufficient to warrant their establishing separate machinery for the selection of farm-mortgage securities.

On the other hand, the larger insurance companies, which invest considerable amounts in farm mortgages, have very well-organized departments, through which they carry on a regular farm-mortgage loan business. They usually limit their loans to territory such as they can approve for this purpose, and hire salaried appraisers, whose inspection of any given individual loan is required before the loan is finally accepted. Ordinarily these companies receive applications through local agencies or correspondents, usually local banks. The application blanks and legal papers used by these insurance companies, including mortgages and notes, have been carefully standardized and adapted to the conditions in the various States where loans are made. While some of the companies show a tendency to make loans at relatively high rates, insurance companies more often represent a highly conservative class of investors in the farm-mortgage business. Their advent into any given State for investment purposes usually leads to a lowering of charges on farm mortgages. Local investors often are governed in their charges by the practices of competing insurance companies.

MORTGAGE COMPANIES.

Figures are not at hand to show the amount of capital invested in farm-mortgage loans by mortgage companies. These companies figure prominently in the farm-mortgage business in all parts of the country, however, and include a number of foreign companies which have invested heavily in farm mortgages in the West South Central, Rocky Mountain, and Pacific States.

There are a number of domestic mortgage companies which have confined their attention to a conservative loan business and have established a reputation for a relatively safe class of investment loans. This has enabled them to build up a clientele of investors, with connections of long standing. Other mortgage companies prefer to handle mortgage loans commanding relatively high rates and commissions. Among the latter are those mortgage companies which limit their business to second mortgages, and receive the extreme figures for both commission and interest.

Mortgage companies may be classified also with reference to the extent of the territory in which they do business. Thus there are those that cover a relatively large territory, including many States, while other companies limit their business to a more restricted area, often a single State or a part of a State. Most of the loans made by either class are placed through local agents or correspondents, although many of the smaller companies also make loans direct to farmers. A mortgage company may buy the mortgage and reassign it to another purchaser, or it may have the paper made out to itself in the first instance, to be resold later. In either case, the mortgage company collects a commission in addition to that received by the local agent or correspondent.

SCHOOL OR LAND-GRANT FUNDS.

In addition to the funds supplied for farm-mortgage loans by insurance companies, banks, and mortgage companies, approximately \$25,000,000 is being loaned from school or land-grant funds directly to farmers in certain States, such as Indiana, Iowa, North Dakota, South Dakota, Oklahoma, Idaho, Utah, and Oregon. The interest charge on these loans is usually 5 or 6 per cent, though in Idaho the rate is 7 per cent. These loans are handled directly from the State departments in North and South Dakota, Oklahoma, Idaho, Utah, and Oregon; in Indiana and Iowa, however, the loans are handled through the counties, which are held responsible for all losses on account of insufficient security or through defalcations by county officers.

PRIVATE INVESTORS.

No figures are available to show the amount of farm-mortgage capital supplied by private investors. It is clear, however, that in certain States, such as New York, Pennsylvania, Michigan, and Wisconsin, the amount of capital supplied by private investors is relatively large.

LOANS HANDLED BY BANKS.

Besides furnishing capital for farm-mortgage loans from their own funds, banks and mortgage companies act as intermediaries or middlemen, purchasing or negotiating large amounts of farm mortgages for insurance companies and other outside investors. The estimated amount of such business handled by banks is shown in the last column of Table 5. In North Dakota the banks negotiate about \$40,000,000 a year in loans for other investors, whereas the amount invested in farm mortgages from their own funds is only one-eighth of this sum. Similarly, in Nebraska the amount handled by banks is more than three times the amount of bank capital invested in farm mortgages. In most of the States west of the Mississippi River, the banks engage rather extensively in the business of handling farm mortgages for other investors.

FACTORS WHICH INFLUENCE THE TERMS ON FARM-MORTGAGE LOANS.

No factor is given greater consideration by farm-mortgage investors, in determining their attitude toward loans in a given area, than the prevailing method of farming. The careful investor in farm mortgages considers all the known factors affecting the income of the farm offered as a security. He studies the relation of the farm income to the price of the land to determine whether the farm value is on a speculative or an investment basis. He is interested in the degree of regularity in income from year to year, and therefore tries to ascertain what crops or products are raised and how far these are adapted to the given conditions. He knows the extra hazards involved in one-crop farming, and therefore inquires about tendencies in the direction of diversified agriculture. He even inquires into the business habits of the farm owners and the kind of care given to the farm products. It is necessary, in general, to understand the importance of differences along all these lines in order to explain the variation in the costs of farm-mortgage loans to borrowers.

Climatic conditions are important because of their effect on the value of the farm security. The semiarid regions of the Western States do not attract capital as freely as the farming sections farther east, where rain is relatively abundant. Important sources of capital, including insurance companies and savings banks, often refuse to loan money on farm-mortgage security where the average rainfall is below

a certain figure. It is still uncertain how far the results of dry-farming methods will be able to overcome the diffidence of conservative investors with reference to loans in semiarid territory.

The character of the soil and the general contour of the country are also important. Capital does not flow as freely to southern Illinois as to other parts of that State, partly because of differences in soil conditions. Similarly, the Red River Valley, in the northern part of Minnesota and North Dakota, attracts capital relatively more freely than north-central Minnesota, largely because of differences in natural conditions. Illustrations of the effect of soil, contour, and climate on the flow of farm-mortgage capital could also be given from other parts of the country.

The distance from financial centers is an important factor. In studying the average interest rates for the different States, a gradual rise in costs is noted as one moves outward from the leading financial centers.

The character of the financial agencies through which farm-mortgage capital reaches the farmer is also of great importance. One needs to consider the part played by agencies that render local savings available for this purpose as well as the kind of facilities through which outside capital reaches the farmers of any given locality. Where local savings institutions have been well developed, as in Iowa or California, the effect on available local capital for farm-loan purposes is readily discerned. On the other hand, the result of a general lack of suitable local savings institutions, as shown especially in many regions of the South and West, is likewise apparent.

THE NEED FOR IMPROVED FACILITIES.

The practice of drawing on outside capital for farm-mortgage loans is found, as has been stated, both in the most highly developed agricultural sections of the corn belt and in the relatively less developed agricultural regions of the South and West. The general need for suitable facilities through which outside capital may reach the farmers in different parts of the country is therefore clear. In the United States it is a fairly well established practice for country banks or real estate firms to act as local agents or correspondents for outside or distant investors, either direct or through other middlemen. It is also the usual practice to market the farmer's mortgage note in its original form. This makes it necessary to find a purchaser who wants a mortgage of a given amount, running for a given time, and with given terms. Obviously, paper of this character will not sell as readily in the open market as standardized securities. Distant investors are not generally in a position to have first-hand knowledge of the farm security underlying a given mortgage note.

Moreover, they often prefer securities running in even amounts for uniform periods of time and with a convenient means of collecting the interest. Many investors prefer to be relieved of all concern as to the keeping up of the underlying security.

All these advantages are secured where the mortgage notes, instead of being marketed direct, are held as a collateral trust fund, and bond issues based thereon are placed on the market. To meet these requirements, institutions are needed, both to fix reliable and suitable standards for farm-mortgage loans, and to market them in the form of bonds. Such institutions can not be properly established without suitable safeguards. It is necessary to profit by the lessons of past American experience, and avoid the mistakes made by the debenture institutions in this country in the eighties and early nineties. The almost complete failure of the farm-mortgage debenture business in 1893 affords ample warning. There is need to take stock of all the factors that contributed to that failure. The granting of loans out of proportion to protection funds, the failure to build up adequate reserves, the basing of loans on boom estimates of land values, the extension of loans on lands of uncertain returns, the substitution of inferior for standard collateral securities, the utter lack of inspection and supervision under State or Federal law—these practices quite naturally led to disaster. As a result there was an almost complete collapse of these early debenture companies.

DESIRABILITY OF STATE AND FEDERAL LEGISLATION.

In order to establish institutions through which farm mortgages may be properly selected, according to reliable and suitable standards, and through which such mortgage loans may be converted into acceptable securities for the open market, it is clearly necessary to have legislation, both by the individual States and by the Federal Congress. The mortgage paper of any State can not be properly standardized without suitable State legislation governing the validity of land titles and the method of foreclosure. Farm-mortgage capital will not flow into a State whose taxation laws render the investment of farm-mortgage capital in other regions more profitable. Every State needs to husband carefully its resources of investment capital by providing suitable legislation for the creation of local savings institutions, as well as associations among borrowers for credit improvement.

At the same time it seems clear that, if the farmers are to obtain adequate connections with the outside capital of the open investment market—connections often involving wide areas, reaching across many States—the problem involved is one too large to be solved entirely by legislation on the part of any individual State. Moreover, a degree of uniformity in supervision and control is needed

which it is doubtful whether State legislation would supply. So far, therefore, as the problem is one of legislation to provide suitable institutions to connect the farmer with the open investment market, Federal legislation seems clearly necessary.¹

CONCLUSION.

Being given a properly organized credit system, it is believed that the farmer who adopts business methods in his farming and thus shows himself worthy of credit will have adequate opportunity to secure it on reasonable terms. The farmers' need in connection with mortgage credit is to obtain investment capital for relatively long periods of time, on suitable terms of repayment, and at the lowest cost consistent with business policy. A properly organized system should supply this need, and, under suitable Federal regulation and control, should protect the farmer against the unreasonable charges now prevailing in many localities.

¹ This bulletin was written before the Federal farm-loan act of July 17, 1916, was passed by Congress.

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A. C. TRUE, Director



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PROFESSIONAL PAPER

July 25, 1916

SCHOOL CREDIT FOR HOME PRACTICE IN AGRICULTURE.¹

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INTRODUCTION.

A new problem has arisen in the administration of rural schools due to the advent of home projects in agriculture and other subjects in which the home becomes the laboratory of the school. To the teacher falls the task of giving a rank for such home work and applying that rank with proper weight to the general scholarship average of the individual.

To the superintendent of schools and other officials falls the duty of determining how much credit shall be allowed; whether there shall be prescribed or optional home work; what shall be the ratio between recitation hours and hours of field work; also the ratio of "boy hours" of labor to "man hours." From farm-management studies acceptable records of labor requirements are to be obtained and these are to be translated into terms of usual school rank and credit. No form of school credit or rank for home work is sure to arouse permanent interest in such work unless related to the credit system used for other school subjects.

This bulletin is intended to assist the rural teacher in her part of this problem and to discuss the basis of such credit for the benefit

¹ Prepared under the direction of C. H. Lane, Chief Specialist in Agricultural Education.

NOTE.—This bulletin is intended to assist superintendents and teachers of rural schools who desire to use home practice in agriculture as an educational feature, giving proper rank and credit on the school records.

of school officials who may desire to install such a plan. Several farm-management studies are utilized which may assist both the teacher and the officials.

METHODS FOR THE TEACHER'S USE.

It is here assumed that the school officials have settled upon the ratio between study and field work, and have also tabulated a more or less elastic statement of the time allowance for different projects. In case this is left to the teacher, it will be necessary for him to study the problems considered in the latter part of this publication.

The home project has been defined by this office as follows: "The term 'home project' applied to instruction in elementary and secondary agriculture includes each of the following requisites: (1) There must be a plan for work at home covering a season or a more or less extended period of time; (2) it must be a part of the instruction in agriculture of the school; (3) there must be a problem more or less new to the pupil; (4) the parents and pupil should agree with the teacher upon the plan; (5) some competent person must supervise the home work; (6) detailed records of time, method, cost, and income must be honestly kept; and (7) a written report based on the record must be submitted to the teacher. This report may be in the form of a booklet." Vacation work will be necessary in many projects.

Since the project is of a longer duration than the practicum elsewhere considered, and since it resembles the more important phases of farm work, the plan of procedure becomes very important; cost, income, and profit are factors which may help to rate the work. Examples of such projects would include the following:

Growing 1 acre or less of corn.

Growing one-eighth acre or more of potatoes.

Growing an acre of peanuts or cotton.

Raising a flock of poultry.

Managing a home garden of not less than one-tenth acre.

Raising one-tenth acre of tomatoes and canning the surplus.

Keeping dairy records, including milk tests.

Raising a litter of pigs.

Raising baby beef.

Picking, packing, and marketing fruit.

Orchard management, pruning, spraying, etc.

The teacher's problems are here considered under several cases, each dependent on the status of agriculture as a school study.

CASE 1. HOME WORK PRESCRIBED.

There should be an assigned value for each subject in the course, and in the case of agriculture a definite part of this value should

be apportioned to the recitation work and the home work separately. The application of a rank then becomes a simple matter, supposing that each home project has been approved at the outset as satisfying the time demands. The teacher will then rank each project, with such advice from experts as may be needed, in view of the evidence available and the reports rendered. This rank is averaged with other school ranks in accordance with the local system of percentages or other forms.

To make this concrete, suppose arithmetic recitations with extra study or preparation periods occur five days in a week and are granted five credits or points in the general average of the term or year. Then agriculture with prepared recitations five times each week would receive five credits. If instead of five recitations it is decided to have three each week and require home practice equivalent to the other two, then home practice would count two-fifths in making up the rank in agriculture. If, however, the practical work is to be rated as though it were a separate academic subject, the authorities would decide as to whether it should be the equivalent of a five-hour course or less.

Whenever this relative weight is fixed, each project should receive its rank in the same way recitation work is ranked and the average will be determined as is customary. This makes real school credit. To illustrate this: In the case where the project is to count as two-fifths of the agriculture, suppose the recitation course is ranked at 85 and the project 90 on the scale of 100.

Rank.	Hours.
85	$\times 3 = 255$ Recitation total.
90	$\times 2 = 180$ Project total.
	5)435

Total rank for agriculture = 87 on basis of 5 credits.

This rank of 87 per cent for agriculture would be averaged as a five-hour credit with other school branches in obtaining the general average rank. In a case where the two periods of practical work are in addition to the five periods of recitation, the total will be seven and the method of averaging will be as in the first case.

It may be the teacher's duty to approve the project and to decide as to how much weight it may have or as to how large a project it must be to equal the requirement for practical work. The school authorities having decided on the ratio as before referred to, it is necessary also to have a ruling as to how many hours of practical work shall equal one prepared recitation. This is usually set for not less than two hours of practical or laboratory work to one recitation period.

Under such circumstances two days of agricultural practice per week would call for not less than 4 hours of home work which, in a

school year of 36 weeks, would amount to 144 hours as a minimum. The total assigned value of the different projects allowed for one year should be not less than 144 hours if the work counts for 2 hours of class work or two-fifths of a full course. It would not be wise to encourage the pupil to carry much more than this unless it is evident that his other school work will not suffer from neglect because of this.

On the basis of 144 hours required, an acre of corn would require about half of this time in sections where the average labor records are above 60 hours per acre. Instead of allowing the pupil to grow 2 acres of corn, in which case the educational value is not increased, it is better to fill the other half of the required 144 hours with some animal project, as poultry keeping. The major part of the work with poultry is not done during the season when corn is grown, and there is a further advantage in applying the lessons on both plant and animal life. If the teacher has a competent advisory committee, it would be feasible to modify the requirements to meet local and individual conditions as in the following study adapted from records in the Office of Farm Management of the United States Department of Agriculture.

On a farm in Orleans County, N. Y., where approximately 20 acres of potatoes are raised as a main crop and approved methods are employed, the following variations are found in three successive years:¹

Variation of hours of labor required to raise an acre of potatoes during different years.

	1911	1912	1913
Yield per acre (bushels).....	207.79	208.50	173.21
Total man-hours (per acre).....	89.13	69.70	72.09
Variations for different operations:			
Plowing.....	7.54	4.98	7.05
Cultivating.....	7.85	9.82	8.12
Hoeing.....	9.38	1.00	4.48
Spraying.....	7.21	5.06	2.51
Picking up.....	22.00	14.30	14.46

Such evidence as this tends to prove that it is not possible to assign a definite number of hours to the raising of a potato crop even with uniform methods, and where the credits granted are in terms of hours of work performed, it would be desirable to use the boy's time record within certain stated limits. In view of the records given above it might be decided that a boy on this farm should put in work equivalent to not less than 70 man-hours in raising an acre of potatoes and that his record for work would be accepted (under inspection) not to exceed 90 man-hours of necessary work. In view of the comparative difficulty of some of this labor for a boy

¹ Part of a record in the Office of Farm Management.

the figures might need revision. The boy might not be allowed to use more than two horses where the father would use four, and some of the manual labor would be heavier for him. In any case the raising of a single acre on this farm would require more than one-half of the 144 hours, assigned to project work.

Again, if the boy is to raise from one-eighth to one-half acre of potatoes only, almost every phase of the work will take more time relatively than it takes on larger fields. Planting, spraying, digging, and even hoeing may be done by hand and a reasonable time allowance is to be made. Such a study of the labor involved will assist in deciding how large a project the pupil should be encouraged to take. Too much project work may detract from the time needed for study; too little may not be worth considering for credit. The extent to which this work is new, and therefore educational, may be a factor in giving different credit for the same number of man-hours labor.

The first thing to be decided is whether the potato project is a suitable application of the agriculture taught. Then in view of the ratio established between textbooks and practice on the one hand and the estimated man-hours of labor in raising an acre of potatoes on the other, determine the question as to whether one-half acre or one-fourth acre or more is sufficient to satisfy the demands.

In case the pupil carries both a crop and an animal project, each may be determined in the same way for the proportionate time allowed. There is a manifest advantage in having both summer and winter projects.

Whenever projects have been carried out and reports rendered by pupils, the itemized records of time should be kept on file at the school to be used in considering future projects. The age and maturity of each pupil should be recorded with each report. These records may in time be of greater value in crediting projects than are the adult labor records which are at present the only available basis.

CASE II. HOME PRACTICE OPTIONAL.

In some cases where the study of agriculture is prescribed for the upper grades, it is not feasible to require any home work. It will then be best to offer added credit for home project work and average the rank on the project with the recitation rank in agriculture as in the former case. The ratio between the two should be fixed upon a fair basis and the same methods for obtaining the cooperation of the parents should be used as in other cases.

If the recitation course runs for three or four periods a week the home work should count for about two-fifths or two-sixths. When there are five recitations in agriculture it may be wise to count home work as three, unless it seems that the pupils ought not to carry that

much outside work. This would give a value of three-eighths to the practical work. Wherever the recitation course is optional, the home work should be a part of that course to be necessary for all who elect the course. In all such cases the methods of applying rank and credit are explained in the first case.

CASE III. NO COURSE IN AGRICULTURE.

In many rural communities where no course in agriculture has been introduced there is already more or less organized project work, which may be utilized by the schools. In some cases this is organized club work and in others it results from the interest and activity of the teachers. Where such conditions exist it is possible to use one of the two methods which have proven successful in some sections of the country.

Correlation method.—The teacher may plan to utilize the home work for the vitalizing of other school subjects. While this should be done, whether there is a course in agriculture or not, it provides a means for linking the school to the home in the absence of such courses.¹

The teacher may have plans drawn, sketches made, problems solved, reports written, and letters prepared as a part of the home project, but credit each on the school rank in drawing, arithmetic, language, and other school branches. While this work is both project work and school work the rank is strictly school rank, and while the pupil is forwarding his project work he is getting real school credit for the educational phase.

Extra subject method.—Other school authorities have decided that home work should be ranked as an extra school subject, carrying weight in proportion to the work done, not to exceed one 5-hour subject. This limit might be made less than five units if desired. Where home work counts as a separate subject we might have the following conditions, based on three hours' credit per week:

	Rank.		Credit.		Total.
Arithmetic.....	80	×	5	=	400
Language.....	85	×	4	=	340
History.....	90	×	5	=	450
Geography.....	87	×	3	=	261
Home projects.....	90	×	3	=	270
			20	)	1,721
General average.....					85

Variations of this plan may be easily made to fit any local system of credits.

¹ This subject has been developed in recent bulletins issued by this department as U. S. Dept. Agr. Buls. 132 (1915), *Correlating Agriculture with Public School Subjects in the Southern States*, and 281 (1915), *Correlating Agriculture with Public School Subjects in the Northern States*.

To decide how much work is necessary to deserve such credits, proceed as in previous cases. In a 36-week year each recitation period per week calls for 2 hours of home work, which is equivalent to 72 hours of unprepared work, and a 5-hour recitation credit would be the equivalent of 360 hours of home work on the same basis. This appears very large and might be more than the authorities would care to recognize, lest it should tend to weaken the other school work. Two or three fifths of this will usually be considered high enough.

There will rarely be found cases where the parents will not be interested in having the pupils take up home projects, but it needs a prearranged plan to insure the kind of cooperation which carries the project to a helpful and successful conclusion. The parents should make an agreement with the teacher before the work begins. It would be best to make a written agreement in which the project is to be outlined and in which the parents agree to certain essentials of cooperation which follow. Oral agreements are less satisfactory.

ESSENTIALS OF COOPERATION.

The parent should agree: (1) To permit the pupil to use specified land, animals, and equipment, either as a temporary owner or as a tenant so far as the needs of the project are concerned; (2) to grant the pupil the time needed for the work and to verify and vouch for the time record; (3) to instruct the pupil in the necessary manipulation so far as practicable; (4) to allow the pupil the profits derived from his own labor and management. The last point is not always feasible, particularly where the pupil takes up one phase of the main business of the farm, such as the weighing and testing of milk for a dairy herd.

The parent must at least give an unbiased voucher of the time and expense record, and a statement that the project work was all done by the pupil. In the absence of an advisory committee or an inspector, the parent is the judge as to when the pupil has accomplished a task successfully.

Where the pupil's time is much needed by the parent in regular home duties it may be well to advise that the pupil take over some part of that home work as a project. This will insure the cooperation of the parents, although the "managerial" income may not come to the pupil.

The school should not only give credit for work for which the pupil receives pay, but should consider the relative income or profit as one important factor in determining the school rank given on the project.

To insure success, it will be very desirable to have a memorandum of agreement signed by all parties before the project begins; a report in full from the pupil, and a voucher from the parent at the end.

A memorandum of agreement might be similar to the following form:

Project agreement.

The parent, _____, agrees to permit his _____, _____, to carry out at home the project of _____ according to the plan submitted, to encourage the pupil and to furnish _____ in addition to the time required; to allow him all _____ animals, equipment, etc.) _____ actual profits from his project; also to check up the time records and vouch for the same.

The pupil, _____, agrees to carry out all the details of the project as agreed upon, to record, and report truthfully upon all items of labor, cost, and income, and to write a full report of all methods to be returned to the teacher. It is estimated that the labor involved will be between _____ and _____ man-hours.

The teacher, _____, agrees to assist the pupil in obtaining information needed and to secure all possible supervision; to accept the work when the project is acceptably completed as equivalent to _____ of school work and to enter the rank for the work and report as a part of the scholarship rank with a weight of _____.

_____, Parent.
 _____, Pupil.
 _____, Teacher.
 _____, Superintendent of Schools.

This should be accompanied by a carefully written plan of work, or printed directions where such projects are organized under State or county leadership.

Parent's voucher on pupil's project.

Name of pupil _____
 Residence _____
 Parent's name _____
 Project _____
 Dates _____

I hereby certify that _____ has carried out the project in _____ in the manner described in his report; that he did all the work, with such exceptions as are noted in his report. ¹ His own labor necessary to the success of his project was _____ hours; hired-man labor, _____ hours; horse labor, _____ hours.

¹ His expense, not including his labor, was _____ \$
¹ His income from all sources _____
 His profit, disregarding his own time _____
 His labor, _____ hours, at _____ per hour _____

Net profit _____
 The _____ exhibited in connection with his report were _____ from his own project, and it is fair to rank him on this basis.

¹ Itemized accounts to be given in written report.

Remarks.....	
	Signed.....
	Relationship.....
Accepted.....	
....., Teacher.	
....., Inspector.	
....., Superintendent of Schools.	
Credit allowed.....	Rank on project.....
.....	Final rank in subject.....

CREDIT FOR HOME PRACTICUMS.

Contrasted with the larger projects are minor processes called practicums in which the element of skill becomes relatively large and there is less management and study required. Such processes as plowing a field, testing seed corn, transplanting tomatoes, or running a separator may be practicums.

If school credit is to be given for doing these things, it seems wise to require a minimum amount of practice and after that have the pupil tested to demonstrate his ability. If his skill is acceptable, give him the credit and rank but once instead of continuing the credits for further practice.

Some processes might be made prerequisites for certain projects, the credit for the project including that for the brief practicums involved. On the other hand, younger pupils might be encouraged to acquire the skill before the years when agriculture is studied as class work.

To make this concrete, consider the case of a boy with an acre of corn for his project. Before he can plow with a pair of horses he should have learned to harness the horses and drive them. Harnessing a pair of horses might then be a practicum for any boy strong enough to handle the heavy harness and previous to that he might have learned to put a light harness on the horse and hitch it to a buggy.

It would be well to allow a limited number of credits each year previous to the seventh grade and to keep a record from year to year of each boy's accomplishments. In some cases it will be possible to hold a public contest in which the pupils will be examined and ranked on their skill in their respective practice. In many cases the voucher of the parent alone will be sufficient. Another plan similar to the Boy Scout classes might be used in which a pupil would qualify for one class by performing a given number of specified tasks and receive a credit at the end of a year or a term. A competition day should be set. When desirable the public may be invited.

Relatively more credit should be given a lower grade pupil for success in one of these accomplishments, such as milking a cow properly or driving a pair of horses. If learning to milk is rated the same as one week's work in any subject for a seventh grade pupil, it may be wise to give twice that credit to a fifth grade pupil for the same work. (Age is perhaps a better basis than grade.)

Skilled workman credits. Agriculture.

Name of pupil.....
 Date of birth.....
 Residence..... Home equipment.....

Credit and rank only after reasonable practice and skill accepted by judge.

Practicum.	Began practice.	Home practice.	Date of test.	Rank.	Age.	Grade.	Credit.	Judge or referee.
Sanitary milking.....								
Running separator.....								
Testing seed corn.....								
Plowing with pair.....								
Butter fat testing.....								
Transplanting tomatoes.....								
Ten farm knots.....								
Add others.....								

Extend this list as local conditions may warrant.

Give to each practicum the number of credits which fairly represent the number of prepared recitation periods needed to accomplish the skillful performance. Bear in mind the time used on arithmetic or other subjects in acquiring skill.

At the end of a term or a year, add all the credits and average the rank for the practical work. This rank should then average with other school subjects, bearing such weight as the ratio of these credit hours bears to the total number of hours for a subject which occurs each school day. If this sum of credits were 45 and the school year is 36 weeks, or 180 days, then the practical work would be the equivalent of $\frac{45}{180}$ or one-fourth of a full five-period course, and the rank should affect the general average with that weight.

If the pupil is studying agriculture, the rank on the practice should affect the rank in that subject first. In lower grades it is often simpler to apply this credit as though it were a separate subject rather than applying it to correlated subjects.

A blank to be filled and signed by the parent might be in some such form as the following:

Credit for skill in agriculture gained by home practice.

..... School.
 I hereby certify that continued home practice in
 (Name.)
 beginning and ending
 (Process.) (Date.)
 and has spent at this work not less than
 (Date.)
 hours.

I consider that he is now skillful in the accomplishment of this process.

Signed.....

Relationship.....

Countersigned....., Teacher.

....., Referee.

Credits..... Rank..... Record.....

(Speed, etc.)

The chief problem is to provide such records and such tests or examinations that the credit may not become perfunctory, thus making the plan a farce.

These practicums should no more be a "snap" for securing school credit easily than should other school work; neither should school credit replace other motives, such as filial respect, willingness to aid others, or loyalty to home and school.

To illustrate concretely how to give credit for practicums, consider that a pupil during the winter term of 12 weeks learns to run a separator and also to test seed corn. Suppose that the separator practicum is considered the equivalent of 5 recitations and the seed testing as 10 recitations and that a rank of 100 is given for the first and 85 for the second. The rank for seed testing counts as two-thirds of the total rank for practicums; hence

Seed testing	$= 2 \times 85 =$	170
Separator	$= 1 \times 100 =$	100
Total to be divided by 3..		270
Average rank for practicums, 90 per cent.		

If the pupil is studying agriculture and has 45 recitations during the term with a rank of 80, the rank for the practicums would average $45 \div 15 = 60$ total periods.

Recitation rank	$80 \times 3 =$	240 or $\frac{5}{6}$
Practicum rank	$90 \times 1 =$	90 or $\frac{1}{6}$
Total to divide by 4..		330
Average rank in agriculture = 82.5.		

In the absence of agriculture as a course, average as follows:

Recitation periods in term	$240 \div 15 = 255$.
Practicums equal	$\frac{1}{2} \frac{5}{6}$ or $\frac{1}{12}$ of credit.
Recitation work counts	$\frac{1}{12}$ or average rank.

All the exercises recognized should be adapted to local conditions. The school officials and competent farmers should be asked to check up the list and settle upon the credits due for each. Record of practice should be submitted.

SAMPLES OF BRIEF EXERCISES.

Hoeing corn, practice until skill is acquired and a test on 50 hills for a rank.

Hoeing potatoes, similar to corn.

Transplanting tomatoes or other plants, the test to be the doing of the work under observation.

Turning crank of milk tester within five revolutions per minute of the required number without a watch. Three consecutive trials.

Running the milk separator.

Milking a cow skillfully and in an approved sanitary way.

Putting light harness on a horse and hitching to a buggy without assistance.

Putting heavy harness on a team and hitching to wagon.

Driving from the seat and turning around where backing is necessary.

Driving a pair of work horses hitched to some farm vehicle or machine.
Driving four horses.
Doing various farm chores.
Feeding a dairy herd according to an established ration.
Tying skillfully 10 farm knots.
Stringing seed corn.
Husking 50 ears of corn in a specified time.
Weeding out garden rows sown in drills without disturbing plants unnecessarily.
Testing hens' eggs for market or during incubation.
Preparing Bordeaux mixture or other spray material.
Learning to sharpen a saw, an ax, shears, or mower knives.
Shocking grain; stacking hay or bundles of grain.
Properly tying a well-filled bag of grain or potatoes.
Properly sewing sacks of onions or other produce.
Cleaning cows or grooming horses.
Cleaning stables.

SAMPLES OF LONGER PRACTICUMS.

This group requires more planning and calls for some conclusions or computations. A reasonable time should be granted, after which the pupil should be required to demonstrate his ability to do the work and to make the proper interpretations of the result.

Testing milk and computing butter fat.
Testing seed corn.
Scoring and grading seed corn and other grains.
Running an incubator.
Sorting, grading and packing fruit.
Planting shade or fruit trees.
Keeping farm accounts from home data.
Running mower or other farm machine.
Plowing and harrowing.
Running the corn planter.
Home mixing of fertilizer.
Making a chicken house.
Using tools to construct or repair pens, houses, etc.
Repairing machines or harness.
Setting a shoe on a horse.
Removing a calf's horns.
Shearing sheep.
Pruning or spraying apple trees.
Running a corn binder.
Breaking a colt.

In these practicums the practice may be discontinued at about the time that the pupil has gained enough skill to make the work profitable.

Further practice will be vocationally desirable but from the school point of view credit should cease except as this practice figures in a project along the same lines, which will occur frequently.

SCHOOL ADMINISTRATION BASIS OF CREDIT.

The following questions arise wherever school authorities may consider this matter:

1. What is the status of agriculture in the rural school law of the State? Prescribed, permitted, or ignored?

2. What bearing have the statutes of the State on prescribing home work or study?

3. What is the attitude of the community in question on these subjects and how far will the local officials support the teacher and superintendent in progressive movements?

4. Is the present home work of the pupils sufficient and may the school work be correlated with it? Or will there be an advantage to the homes as well as the school if credit is given for organized and supervised school work, and will the parents welcome this plan?

5. May it be advisable to assign definite numerical credits for each subject in the grades as is usually done in the high school? What complications would be added if home work in certain lines were given a similar credit? Would such credit be of any real value unless its possession would assist in gaining promotion or graduation?

So far as possible the superintendent of schools (with the local school committee, if they are interested) should agree upon the basis of school credit for home work in agriculture, leaving to the teacher only the individual application and ranking. These officials should first appreciate why school credit is to be given and should decide upon the amount of home work to be recognized, its character, its ratio to school work and the general method of applying the credit. The assignment of values to various projects will be necessarily based on farm management studies. Some suggestions along this line follow this section.

Why give school credit?—Without practice at home or elsewhere the textbook course in agriculture would appear to have but little value. In the secondary schools it is customary to require in all branches so much work of the pupils that some of it must be done at home. In some elementary schools a similar requirement is made but this will not be tolerated in some sections as prescribed work.

Wherever such a requirement is common it would seem desirable that the pupil should take home for study or practice such subjects as may arouse home interest and cooperation and detract as little as possible from the family life. Required study of agriculture and home economics, rural-survey work, and correlations of such work with other branches would seem to meet these demands. Home practice in the garden or with the flock would seem even better than home study.

In such cases the school should require home projects in connection with the school course in agriculture and give a rank on the practical

work as well as on the study. Such a rank might average with the recitation rank on the basis of from one-fourth to one-half, according to circumstances as previously explained.

In communities where no home study may be demanded it is probable that most parents would encourage home project work so closely allied to family interests. In this case the required course in agriculture might, if required, be given additional weight for such home work. If five credits are given for the recitation course then seven or more might be allowed when the project work is completed in a satisfactory way. This method dignifies such work and gives it the rating of real school work.

What kind of credit?—In the secondary schools each subject has assigned a numerical value based upon the amount of work or the number of hours of recitation each week. A minimum requirement is made of the total hours of work necessary for promotion or graduation, and a pupil who elects to pursue a given subject knows how much it counts toward this minimum.

In the administration of rural schools it is unusual to find such an arrangement of credits with a minimum for promotion, so there is no obvious advantage to the boy who gets extra credits, so far as school advancement is concerned.

Any scheme of holidays, prizes, or other perquisites is evidently not school credit in the sense in which we deal with arithmetic and language. Either the rank given for home work must be applied to the correlated study in school or the units of credit given for home work must be based on units of credit in academic subjects and so arranged that these credits advance him toward a school goal.

Where the home project is a required part of the study of agriculture this is of less importance, since the rank in agriculture includes the practical work. Whenever this may be optional, there is an obvious advantage in giving credit that means something in terms of school work.

The school authorities may find it desirable to assign numerical values to all school subjects and place home projects in the list. It is possible to fix a minimum for promotion and to promote by subjects rather than by grades in the rural school.

In some cases other methods have been used, but the relation to academic credit is not as clear. Among these might be mentioned the following: (1) Holidays given for a given number of credits; (2) promotion at a lower grade; (3) automatic and arbitrary raising of lower grades without reference to their relation to the project; (4) honors or "cum laude" promotions, and (5) prizes and other rewards. Since these credits bear little relation to the work done,

such methods should be adopted only with caution and when it is impracticable to give real academic credit.

What ratio for practice?—School courses which have included laboratory work are often arranged for three recitation days and two laboratory days in each week. On the laboratory days two or more recitation periods are considered the equivalent of one prepared recitation, and the ratio of recitation to laboratory is then computed as 3 to 2. The school officials or whoever lays out the course should first decide on what this ratio shall be. The next point is as to how many hours of home work, not constantly under supervision, is the equivalent of one prepared recitation. Possibly an hour's work in the field is not the equivalent of an hour in the laboratory where the work is under the direction of a teacher. Since the class period in the grades is less than an hour, it may be fair to consider two hours of home work the equivalent of one prepared recitation period.

How much credit?—According to the plan mentioned, 72 boy-hours of work during the year will be necessary for each credit to be granted not to exceed five credits. Farm management studies and the analysis of farm records have given certain averages which may be taken as a guide under average conditions and may be modified to meet exceptional conditions. Such modifications should be made by a committee which might include, besides the teacher, the local superintendent of schools, the county agent, and one or more representative farmers.

It is obviously an advantage to avoid disagreement at the end of the project by settling at the outset how much credit will be granted for a given amount of work. If the amount of labor usually required for a given work is known or can be estimated in "man-hours," then a decision that a prepared recitation is the equivalent of two man-hours (or more or less) will fix the credit value of the project.

On the basis of a year of 36 weeks, 5 recitations a week or 180 per year would be the equivalent of 360 man-hours per year in home project work. This ratio needs revision whenever the discrepancy between "man-hours" and "boy-hours" of labor becomes large. In some types of work a boy is capable of greater progress than is a man, while in other work the boy would make relatively slow progress. The boy should not be encouraged to do too heavy work on his project, and where there are several new processes to be learned it may be wise to count the boy's time at full value. Future records of boys' labor on these different home projects will enable teachers and superintendents to rate these projects more accurately, but very many records will be needed in view of the diversity of boys' work.

A method less frequently used which appears quite practical is as follows: During the last two years of the elementary grades a pupil may obtain credits for home work which may equal not more than one 5-hour course of prepared school work. This divided between the two grades would make $2\frac{1}{2}$ hours per week of academic credit, or on the basis of our previous discussion, 5 hours or more of home work per week for two school years. If this is not required, it should at least be elective, with some weight as an alternative. Such a method would equal approximately the amount of credit given when two days of practical work were credited each week under other methods.

In the secondary school, where there is usually an established system of credits, the application of these principles should be a simple matter, especially where the home project is a required part of the course in agriculture.

Whenever it is practicable, the superintendent should provide the teachers with lists of projects which may be used in the district and the usual labor ranges reduced to a basis of schoolboys' work. Such a form as the following might be used based on local records:

Home projects for the School. Grades 7 and 8.

Project.	Unit.	Maximum time.	Minimum time.	Desirable range.
Growing corn.....	1 acre.....	86 hours..	70 hours..	$\frac{1}{2}$ acre to 1 acre.
Care of laying hens.....	25 hens; 1 year.	140 hours..	100 hours..	6 to 50 hens; 6 months to 1 year.

Extend the list to cover all ordinary projects.

Whenever credit is given for home practicums a similar guide should be prepared for the teacher.

Home practicums for the School. Grades 5 to 7.

Practicum.	Minimum practice.	Equivalent to recitations.	Required test.
Running separator.....	3 consecutive weeks.....	5	3 times; speed within 5 revolutions.
Hoing corn.....	$\frac{1}{2}$ acre.....	6	50 hills observed.
Testing seed corn.....	2 separate tests. 50 ears. Records.	10	Demonstration to teacher.

Supervision of projects.—In the estimation of many educators, the success of the whole project and credit plan depends on supervision, especially during the vacation months. The frequent visits of an inspector who will check up the work done and advise on the impending needs stimulate the pupil during those weeks when neglect is most probable. Usually pupils begin with much enthusiasm but have too little persistency to stick to a monotonous task alone

without some encouragement. Furthermore, the problems which arise during the vacation weeks are often critical and the pupil needs help.

Among the different methods of providing this supervision a few are named. In each case the supervisor must be capable and willing. Perfunctory supervision soon fails to accomplish the desired end.

1. High-school instructor of agriculture employed during the summer months to supervise all projects.

2. A local committee cooperating with the county agent, the latter to advise regularly and visit projects at least once during the summer.

3. A committee of the "parent-teachers association." With changing teachers this is valuable.

4. The local club leader cooperating with the extension service of the State agricultural college, with or without a local committee.

5. Local experts in plant or animal production might well be paid for a few such rounds of visits.

6. Resident teachers sometimes qualify as supervisors.

FARM MANAGEMENT BASIS OF SCHOOL CREDIT.

If the exact amount of labor for growing each crop and the ratio between projects could be definitely stated, this problem would be greatly simplified. It happens, however, that variations in the labor required for any project due to factors not entirely within control would not allow the use of averages in all cases. A study of the tables appended to this study (see pp. 21 to 27) will show that the labor on any given project varies much in different localities and under different conditions.

In Table 1, page 21, are shown the number of man-hours and horse-hours of labor in certain farm activities in a few States. It is evident that the averages often fail to apply to any one State. These figures, which are taken from unfinished studies in the Office of Farm Management, are to be weighed by further records but are sufficient for all purposes of this bulletin.

The succeeding tables show the variations in labor requirements and tend to prove that it is difficult to apply any average figures even for one State. They also suggest some of the factors that may vary the labor requirements of any project in a given community. The available studies are more detailed for some crops than for others and there is less information which will apply to animal projects.

The following method is suggested for any district in which there are no records to use as a basis for credit. From the figures quoted in the tables select those which apparently apply most nearly to the given locality. Determine upon a range of variation which will be allowed in giving the credit and ask the pupils to keep accurate records for the labor on their projects. It would be desirable also for

the pupils to keep labor records on different crops on their parents' farms, these to be used in arithmetic class problems and then compiled for the purpose of fixing a local basis for giving credit.

Factors causing variations.—Aside from the question of proper management and steady work there are several factors which very evidently affect the labor requirements of any project. In Tables 2, 3, and 4, adapted from Bulletin 266 of the Ohio Experiment Station, it is shown that the harvesting method, the size of the field, and the shape of the field each influences the labor requirements. Without doubt a small field will usually be used by the pupil.

In case any insect pest or disease comes upon the crop, the experience of fighting these doubtless has an educational value and deserves credit even if the extra labor diminishes the profit. This is quite different from extra labor due to poor methods or mismanagement.

It is also true that the character of the soil, the slope of the land, and local climatic variations will all influence the labor requirement and if some competent referee considers the records in view of these factors he may properly rate each project.

Labor in garden projects.—Because of the great variation in the crops raised in a garden and the local factors involved, only a few general suggestions may be given.

Family gardens of from one-twelfth to one-eighth acre would appear suited to pupils of the upper grades. This estimate will not fit all cases. Gardens comprising largely such crops as corn and potatoes demand relatively less time. Gardens having a large variety of vegetables, so planted as to need intensive cultivation, take more time and provide more education in the single project. The use of cold frames or a hotbed, growing succession crops, and either marketing or canning the surplus vegetables deserves added credit. After such projects have been carried out and itemized, if records are filed, the teacher and his advisers will be able to estimate in advance for future cases. The main issue is to map out a reasonable amount of work in view of the course and the credit given, and then require excellence in the work. Good practice and fair crops are as much an evidence of what the pupil has learned about gardening as any textbook recitations and examinations could be. Where one crop is raised, as tomatoes for canning, less experience may be gained in the season's work. If the pupil does the canning, however, this phase of the work deserves credit.

Where an animal project, particularly poultry, is carried at the same time, the results are better from an educational point of view than where a larger crop project is carried alone. Garden waste, as green food for the hens and hen manure for the garden, are examples

of the interlocking of two projects. Furthermore, they will illustrate more fully the school lessons in agriculture.

Small-fruit projects could rarely be considered complete in one season and the practice is quite different the second season. In some localities it might be wise to take up such a project with a two years' plan mapped out. Such a fruit garden would be from one-fourth to one-tenth acre, depending on the crop. (See Tables 10 and 18.)

PROJECTS WITH ANIMALS.

Nearly all the statistics available concerning labor in the care of animals refer to conditions quite unlike those existing in most project work. These figures have some value, however, as a starting point.

Poultry.—The table of labor requirements on page 21 gives 226.6 man-hours and 19 horse-hours required for 100 hens in New York or 128.5 man-hours and 16 horse-hours on an average of all studies. It may be evident that this ratio of 1.28 hours labor per hen would not hold for small flocks. It is more probable that with ordinary facilities it might take the boy as many hours to care for a flock of a dozen or 25 hens as the poultry man needs for 100.

A boy reported on his poultry project with 12 hens as taking one-fourth hour of work each day and three-fourths hour once each week for mixing feed, cleaning, and other extra work. This would amount to 130 boy-hours per year, not allowing for building, repairs, incubation, or care of chicks.

The work done by the pupil in caring for a small flock of poultry may bring educational returns commensurate with time spent up to a certain degree. Time spent in weighing feed, trap nesting, and making detailed records is worthy of credit and until enough local records have been compiled it may be wise to depend on the boy's corrected time sheet. Inspection of his work should help to make this record dependable. He should be advised not to charge the time spent in petting the animals or other ways which are not to be counted as productive labor.

Other animals.—Projects with other animals will vary much. The work which is repeated daily, like all farm chores, is educational for a while or until proficiency is attained. Ability to continue at the same task in a monotonous way until an end has been gained is a desirable farm habit. On the other hand, it is better to introduce feeding records, production tests, and other problems and to have the projects so laid out as to include a variety of experiences. Some of the processes may be standardized. As an example, let a boy feed, milk, and otherwise care for two cows for the winter season. Have him weigh the milk each day and twice each month test the milk for butter fat.

In a New Hampshire study it was found that a man would average to milk properly about seven cows in an hour, weighing and recording

the milk. The handling of the milk and cleaning utensils twice a day was figured at one hour a day for a small herd, while the care of the cow, feeding, preparing feed, cleaning cow and barn averaged about 20 minutes each day per cow.

If the cost accounts, labor, milk records, and butter fat computations are used in school problems, there would seem to be reason to give full credit for the time spent even in routine work. It would obviously not be desirable to give the same credit for a second season on such a project.

SUMMARY.

1. The home farm may be the logical laboratory for practical work connected with rural school agriculture. Home work carried on for this purpose may properly be given school credit just as home study of arithmetic gains credit.

2. The relative importance of a project from the school point of view depends upon its relation to school study; the amount of education involved; the improvement of the pupil in skill, method, or knowledge; the results or relative success measured partly by crops or profits; and the reports, essays, exhibits, and other evidence given at school.

3. The weight given should recognize, besides the educational factors, the period covered by the project; the hours of labor involved and the relative difficulty; the evidence of good management; the emergencies met and pests combated; and the success of adults in the same line of work during the same season.

4. The rank should depend on evidences of honest endeavor and thoughtful application of instructions.

5. Both weight and rank should be based upon the usual methods of ranking and crediting school subjects. Manual practice should not receive too much or too little relative recognition.

6. Until local records are compiled and analyzed from boys' and girls' projects, it will be best to use the most available records of man labor, modified as to relative difficulty, number of new operations involved, and other factors. These estimates may be gradually modified as experience is gained. The educational feature should always be kept in mind.

SUPPLEMENTARY TABLES OF LABOR REQUIREMENTS.

The following tables are selected with a view to assisting the school officials and teachers in three ways. In the first place, they tend to verify the statement that uniform records are not obtainable and that this problem is more or less local. It is also hoped that they give evidence of some of the factors which need consideration. Finally, it is probable that the selection and adoption of units and ratios from these tables may prove a good starting point in any community, these figures to be modified as local records are compiled.

TABLE 1.—*Labor requirements for different crops.*

[Average number of hours by sections, and the average of all the sections; also man and horse labor rates.]¹

Enterprise.	Illinois average.		New York average.		Iowa average.		Pennsylvania average.		Total average.	
	Man.	Horse.	Man.	Horse.	Man.	Horse.	Man.	Horse.	Man.	Horse.
Corn (grain), per acre	20.6	45.2	77.0	59.3	23.1	51.0	67.6	42.5	47.8	51.9
Silage, per acre.....			43.2	55.7	34.5	61.7	58.3	50.9	43.9	57.1
Potatoes, per acre.....			97.6	81.8	51.8	89.7	122.9	95.8	87.6	85.6
Alfalfa (harvesting).	14.0	15.0	(3 cuttings)		22.9	31.6	34.4	19.6	20.6	22.1
Apples (bearing), per acre.....									162.3	53.4
Horses, per animal unit.....	79.1	9.0	118.7	6.3	99.6	3.7	151.5		101.8	7.1
Cows, per animal unit.....	126.2	16.8	153.4	8.2			175.8	17.5	142.0	12.3
Poultry, per 100-hen unit.....			226.6	19.0					128.5	16.0
Manure, per ton.....	1.8	3.5	1.2	1.8	.9	1.7	2.1	2.6	1.5	2.4
Oats, per acre.....	11.4	21.9	19.7	25.2	14.6	23.8			15.7	23.7
Wheat (seeding), per acre.....	7.0	27.3	10.6	21.5	4.9	18.7	12.3	27.7	9.0	22.6
Wheat (harvesting), per acre.....	14.0	17.2	9.9	7.6	12.5	12.5	25.1	23.4	12.3	11.5
Wheat (complete), per acre.....			25.9	39.2	15.9	22.8			20.9	31.0
Beef cattle, per ani- mal unit.....									27.7	15.5
Sheep, per animal unit.....									33.9	6.7
Peaches (bearing), per acre.....									90.5	33.8
Pears (bearing), per acre.....									116.7	45.1
Timothy hay, per acre.....									10.2	9.1
Timothy seed, per acre.....									8.7	9.2
Clover hay, per acre.....									12.3	12.2
Mixed hay, per acre.....									9.6	9.1
Labor rate, per hour.	\$0.164	\$0.105	\$0.155	\$0.165	\$0.127	\$0.123	² \$0.091	² \$0.072	\$0.154	\$0.129

¹ Adapted from unfinished studies of the Office of Farm Management, U. S. Department of Agriculture.

² North Carolina.

An illustration of these variations and the factors involved is given in a study of the labor cost in producing corn in the State of Ohio.¹

TABLE 2.—*Variation in labor cost of producing corn in Ohio.*

Methods used or factors involved.	Man-hours of labor per acre.			Methods used or factors involved.	Man-hours of labor per acre.		
	Maximum.	Minimum.	Average.		Maximum.	Minimum.	Average.
Harvesting method:				Size of fields—Con.			
1. Grain harvested.	97.60	40.64	48.18	3. From 5 to 10 acres			62.03
2. Hogged off.	30.30	12.38	23.38	4. From 10 to 15 acres			56.63
3. Silage.	73.92	40.49	57.21	5. From 15 to 20 acres			50.76
4. Contracted in part.	68.98	20.19	43.96	6. From 20 to 25 acres			36.20
Sections of the State:				Shape of field:			
Southeast.			69.68	1. Less than 2½ acres	² 83.58	³ 87.47	84.79
Northeast.			68.53	2. 20 to 25 acres.	² 22.91	³ 42.48	36.20
Northwest.			50.06				
Southwest.			36.04				
Size of fields:							
1. Less than 2½ acres			1 84.79				
2. From 2½ to 5 acres			59.53				

¹ Note the relatively large amount of labor on the fields of less than 2½ acres. This difference would be still greater on fields of 1 acre or less.

² Rectangular.

³ Irregular.

TABLE 3.—*Average amount of labor for different parts of the work on corn in Ohio.*

[Adapted from Ohio Station Bulletin 266.]

Groups of items.	Man-hours.	Horse-hours.	Approximate per cent of total labor cost.	Groups of items.	Man-hours.	Horse-hours.	Approximate per cent of total labor cost.
Preparation of seed bed.	7.92	20.58	24	Fertilizing.			11
Planting.	1.78	2.02	4	Overhead labor.			4
Cultivating.	9.89	13.16	21	Care of seed.			1
Harvesting.	20.98	12.40	34	Miscellaneous.			1

The more detailed analysis indicates the relative value to be credited for various operations. Where an operation like harrowing or cultivation is repeated the number of man-hours would be increased accordingly. The following table covers nearly all combinations:

¹ Adapted from Ohio Agricultural Experiment Station Bul. 266 (1913).

TABLE 4.—*Labor requirements for corn per acre once over in Ohio.*

[Adapted from Ohio Station Bulletin 266.]

Operation.	Hours per acre.		Operation.	Hours per acre.	
	Man.	Horse.		Man.	Horse.
Manure.....	11.79	17.65	Cultivating—Continued.		
Care of seed.....	.81	.08	Cultivating, 2 horses.....	1.68	3.36
Preparation of seed bed:			Hoing.....	12.23	-----
Plowing.....	5.44	13.16	Harvesting:		
Harrowing (spike).....	.99	2.68	Cutting by hand.....	9.06	-----
Disking.....	1.02	2.96	Cutting by machine.....	2.53	3.86
Planking.....	.93	2.51	Cutting silage corn by		
Rolling.....	.76	1.61	machine.....	2.59	5.00
Planting:			Shocking.....	3.53	-----
Marking out, 1 horse.....	1.58	1.58	Picking up ear corn after		
Marking out, 2 horses.....	.76	1.52	binder.....	1.61	2.23
Planting by hand.....	2.38	-----	Filling silo ¹	23.23	19.50
Drilling.....	1.50	1.82	Husking by hand.....	14.41	-----
Planting, 2 horses.....	.93	1.86	Hauling corn ²	3.90	6.45
Replanting.....	1.85	-----	Hauling fodder ²	2.45	3.34
Replanting part area.....	1.17	-----	Snapping, jerking, and		
Cultivating:			husking from stalk....	10.77	13.80
Harrowing after planting.....	.71	1.64	Husking and shredding...	12.73	12.02
Rolling after planting.....	.70	1.40	Shredding.....	4.95	4.33
Using weeder.....	.74	.74	Hauling shock corn.....	7.15	9.05

¹ Includes the time for cutting the corn in the field. ² After corn has been husked from shock in field.

The following data were obtained in a southern area studied by the Office of Farm Management of the U. S. Department of Agriculture:

TABLE 5.—*Labor on corn, Coastal Plain, central Georgia.*

[77 records, average yield 24.5 bushels per acre.]

Operation.	Man-hours.	Mule-hours. ¹	Operation.	Man-hours.	Mule-hours. ¹
Cut stalks, plow and harrow..	7.5	9.4	Harvesting.....	7.0	3.5
Lay off, bed, etc.....	2.5	3.6			
Plant, fertilize, cultivate.....	13.1	13.7	Total.....	40.4	30.2
Pull fodder (295 pounds per day).....	10.3	-----			

¹ Note the relatively small amount of mule labor.

These conditions are average rather than ideal, as the yield of 24.5 bushels testifies, but it is not evident to what extent the figures would be modified by improved practice. Factors which are found in intermediate States are illustrated in the following list of operations. Not all of the operations were used on any one field.

TABLE 6.—*Labor on corn, Warren County, Ky.*

Operation.	Man-hours.	Horse-hours.	Operation.	Man-hours.	Horse-hours.
Manuring.....	10.0	20.0	Thinning.....	2.0	-----
Breaking.....	4.0	12.0	Cultivating, 4½ times.....	6.0	12.0
Rebreaking.....	4.0	12.0	Cutting and shocking.....	6.6	-----
Disking, twice.....	2.6	10.4	Pulling ears.....	7.7	-----
Harrowing, twice.....	2.2	4.4	Cribbing.....	2.0	2.0
Drag.....	1.1	2.2	Hauling fodder.....	3.3	6.6
Rolling and laying off.....	1.4	1.4	Shredding.....	13.4	15.5
Planting.....	.7	1.4	Silo.....	20.0	23.0
Harrowing.....	2.2	4.9			

TABLE 7.—*Labor on eight farms in Arkansas.*

Crop.	Man-hours.	Horse-hours.
Corn.....	41.75	44.28
Cotton.....	69.40	36.50
Sweet potatoes.....	104.30	61.30

TABLE 8.—*Labor on cotton, Coastal Plain region, Georgia.*

[85 records, average yield 0.63 bale per acre.]

Operation.	Man-hours.	Mule-hours.	Operation.	Man-hours.	Mule-hours.
Cut stalks, plow, harrow.....	8.3	17.6	Haul to gin (average haul 2.5 miles), 225 bales per day....	2.8	5.6
Lay off, bed, etc.....	4.2	4.8	Marketing lint.....	1.9	3.8
Plant, fertilize, and cultivate..	18.1	18.8			
Chop and hoe.....	13.5	-----	Total.....	111.8	50.6
Picking (average 150 pounds per day).....	63.0	-----			

The number of man-hours may be reduced by using more mules and the yield may be increased by better practice. The increased yield would require more picking and possibly leave the total man-hours much the same. Pupils' records on cotton projects should prove helpful.

Man-hours of labor on potato crop.—A few districts selected from those covered by farm management studies will demonstrate the variations in the amount of labor required to raise an acre of potatoes in different parts of the country. A large number of farms were averaged in each section and in each case there was much variation even in the same county. These statistics are based on areas large enough to lead us to expect efficient use of labor. The number of horses used may account for some variations, soil conditions and methods for others. In some cases the picking up was done by contract labor but this is not averaged in with the other fields. Where contract labor is used the figures would be of little value for school estimates.

The following districts were selected as showing enough variation and a sufficient number of farms to be representative: Districts—1, Aroostook County, Me.; 2, Steuben and Schuyler Counties, N. Y.; 3, Waushare, Portage, and Waupaca Counties, Wis.; 4, Clay County, Minn.; 5, Monmouth County, N. J. (cover crop); 6, Charleston County, S. C.; 7, St. Johns County, Fla.; 8 Montrose County, Colo. (irrigated). The labor variations in these districts were as follows:

TABLE 9.—*Variations in amount of labor required for different operations in raising an acre of potatoes.*

Processes.	Man-hours per acre by districts.							
	1	2	3	4	5	6	7	8
Clearing land.....					1.5	2.9	3.0	-----
Plowing.....	5.3	5.3	3.6	2.6	3.2	5.4	4.2	5.2
Preparing seed bed.....	5.3	7.4	2.1	1.0	3.7	4.7	6.6	1.5
Hauling fertilizer.....	3.4	7.0	-----	-----	1.8	4.0	6.0	-----
Preparation of seed.....	6.6	4.3	3.2	3.7	6.2	-----	7.0	4.3
Applying fertilizer.....	-----	1.0	-----	-----	-----	2.0	2.0	-----
Planting, machine.....	2.9	4.4	-----	1.6	2.6	-----	3.7	2.5
Planting, hand.....	-----	3.5	3.2	-----	-----	6.7	10.0	-----
Harrowing, after planting.....	-----	1.0	1.5	1.5	2.4	1.4	1.0	6.0
Cultivating.....	13.7	17.3	9.8	6.8	14.2	26.0	10.9	10.2
Spraying, machine.....	3.7	-----	1.6	.8	1.0	3.2	2.2	1.0
Spraying, hand.....	-----	-----	-----	-----	-----	4.4	-----	-----
Digging, machine.....	4.3	2.5	2.3	1.9	2.6	3.0	-----	2.2
Digging, hand.....	-----	19.2	-----	-----	-----	18.7	28.8	-----
Picking up, by hand.....	16.4	13.5	11.1	-----	20.0	27.7	24.2	-----
Hauling and marketing.....	12.4	15.0	18.0	17.8	8.3	6.4	8.8	21.9
Irrigating.....	-----	-----	-----	-----	-----	-----	-----	5.5

Contract labor not included above.

Total labor, maximum, 125 hours; minimum, 29 hours.

Average for Aroostook County, Me., 67.5 hours.

Variations in Minnesota district, 29 to 80 hours.

Variations in Wisconsin district, 36 to 109 hours.

Other potato data will be found in the body of the text on page 4.

TABLE 10.—*Labor required per acre for strawberries, Bowling Green, Ky.*¹

First year.	Man-hours.	Horse-hours.	Second year.	Man-hours.	Horse-hours.
Manure.....	20.0	40.0	Mulch.....	10.0	10
Breaking.....	4.0	11.2	Pick.....	320.0	.....
Rebreaking.....	4.0	11.2	Pack and grade.....	32.0	.....
Disking.....	2.5	7.5	Nail boxes.....	16.0	.....
Harrowing twice.....	2.0	6.0	Hauling.....	17.0	35
Lay off twice.....	2.0	6.0	Bar off.....	3.3	33
Planting.....	33.3	.....	.....	1.6	32
Cultivate 10-20.....	49.5	49.5	Cross harrow.....	4.0	8
Hoe.....	24.0	48.0	Cultivate.....	50.0	50
	40.0	.....	Hauling.....	25.0	50
				4.0	.....

¹ Two and three horse teams were used except in some of the cultivating.

Since the picking and marketing is so large a part of the labor and must vary with the crop, totals would be of comparatively little value here. These items will serve as a guide in inspecting a record, however.

TABLE 11.—*Selected miscellaneous estimates.*

[Adapted from studies in New York State.]

Project.	Man-hours.	Horse-hours.	Project.	Man-hours.	Horse-hours.
Hay and alfalfa, each cutting..	10.0	10.0	Sheep, each.....	5.0	0.3
Corn, all kinds, per acre.....	60.0	70.0	Brood sow and pigs until weaned.....	30.0	5.0
Beans, per acre.....	50.0	50.0	Other hogs, each.....	5.0	1.0
Potatoes, per acre.....	120.0	100.0	Poultry, per head.....	1.5	.2
Root crops, per acre.....	150.0	120.0	Pullets, per head.....	1.5	.2
Truck crops, per acre.....	150.0	150.0	Bees, per swarm.....	3.0	.6
Truck crops (per \$5 received).....	10.0	10.0	Retail milk, per cow.....	150.0	150.0
Cows, each.....	150.0	20.0			

The following table copied from Farmers' Bulletin 661, Method of Analyzing the Farm Business, gives standards which may be modified as local experience may render advisable:

TABLE 12.—*Approximate work units needed for the production of crops and in caring for live stock, etc., a work unit being a 10-hour day of man or horse labor.*

Operation.	Work units (10-hour days).	
	Man.	Horse.
Production of crops (per acre):		
Timothy, alfalfa, and clover hay, per cutting.....	1	1
Oats, wheat, barley, rye, buckwheat, and miller.....	2	3
Corn husked from standing stalks, corn-belt States.....	2 to 3	5
Corn husked from shock.....	6	6
Corn for silo.....	4 to 6	5 to 7
Corn husked, Southern States.....	3 to 4	3 to 4
Potatoes.....	8 to 12	10
Cotton.....	8 to 12	4 to 6
Sugar beets.....	7	7
Melons.....	4	2
Cabbage.....	13	12
Peanuts.....	4	1
Sorghum sown broadcast, cut for hay.....	4	4
Tobacco.....	20	7
Field beans.....	5	5
Apples.....	15	5
Caring for live stock (per year):		
Horses, corn-belt States.....	8	$\frac{1}{2}$
Horses, Eastern States.....	12	$\frac{1}{2}$
Dairy cows.....	15 to 20	1 to 2
Young stock, cattle, colts, etc.....	2½ to 3	$\frac{1}{16}$
Ten hogs, corn-belt States.....	10	2
Ten hogs, Eastern States.....	20	2
Ten brood sows and raising pigs to weaning.....	30	5
100 ewes.....	50	5
100 chickens (well cared for).....	15 to 25	1

SELECTED CLUB RECORDS OF BOYS' AND GIRLS' WORK.

Up to the time this list is compiled, club work has varied much in the several States and labor records have not as yet formed a basis for estimates of credit. Some records are available in detail and others as summaries; some were based upon one conception of labor units and some on another idea. Yet the figures which follow should give some assistance in making estimates until such a time as the local records become a satisfactory basis of credit. If boys and girls are led to take an interest in getting these accurate records rather than to subordinate everything to winning prizes, the value of their records will be considerable.

TABLE 13.—*Specimen labor records of corn-club boys in Northern States.*

State.	Preparation of land.	Planting.	Cultivating.	Hoeing.	Gathering.	Total.	Yield.	Cost.
							<i>Bushels.</i>	
New York.....{	21	2½	11	13	40	87½	61	\$26.40
	10	17	14	53	110	194	40	31.30
New Jersey.....{	8	1½	10	-----	20	39½	102	21.05
	8	1	2	-----	50	61	94	51.25
Pennsylvania.....{	45	3	15	-----	32	95	93	28.75
	6½	1½	6	12	9	35	84	11.45
Iowa.....{	10½	1½	4½	1	30	47½	120	16.13
	4	1	6	10	10	31	88	10.90
Illinois.....{	10	¾	5	-----	8	24	48	10.58

TABLE 14.—*Georgia corn-club labor records.*

	Preparation.	Cultivation.	Harvesting.	Total.	Yield.	Cost.
					<i>Bushels.</i>	
Boy 1.....	13	9	6	28	50	\$12.50
Boy 2.....	18	7	15	40	59	33.62
Boy 3.....	16	26	64	96	103	37.72
Boy 4.....	9	30	15	54	57½	25.16
Boy 5.....	16	16	30	62	147	33.70

TABLE 15.—*West Virginia corn-club labor records.*

	Preparation.	Cultivation.	Harvesting.	Total.	Yield.	Cost.
					<i>Bushels.</i>	
Boy 1.....	11½	19	30	60½	150	\$23.50
Boy 2.....	15	31½	30	76½	55	19.90
Boy 3.....	31	15	50	96	60	14.30
Boy 4.....	13	55	35	103	48½	18.45
Boy 5.....	33	45	35	113	49	24.00
Boy 6.....	14	17½	35	66½	83½	29.59

The average of 12 West Virginia boys, who raised 100 bushels or more of corn, was 103 hours of labor per acre.

TABLE 16.—*Arkansas corn-club labor records.*

	Preparation.	Cultivation.	Harvesting.	Total.	Yield.
					<i>Bushels.</i>
Maximum.....	36	48	26	92	142
Minimum.....	4	5	6	17	32
Average.....	15	20	14	48½	75

Maximum labor record gave minimum yield.

Men's average for the same section, 47.8 hours.

TABLE 17.—*Selected corn-club records from Mississippi.*

	Prepara- tion.	Cultiva- tion.	Harvest- ing.	Total.	Yield.	Cost.
					<i>Bushels.</i>	
Boy 1.....	16	10	10	36	54	\$26.50
Boy 2.....	37	32	16	85	55	24.45
Boy 3.....	18	30	16	64	74	27.90
Boy 4.....	7	20½	15	42½	52½	19.62
Average.....	18.6	32.4	12.6	62.6	56	24.38

Ten boys with average yield same as average corn yield for the State.

TABLE 18.—*Selected Texas corn-club records from average conditions.*

	Prepara- tion.	Cultiva- tion.	Harvest- ing.	Total.	Yield.	Cost.
					<i>Bushels.</i>	
Boy 1.....	13	12	14	39	90½	\$12.15
Boy 2.....	11	12	8	31	43½	17.71
Boy 3.....	7	16	4	27	30	8.80
Boy 4.....	9½	20	10	39½	19	12.95
Boy 5.....	7½	13	6	27	32	20.50

TABLE 19.—*North Carolina corn-club records 1914.*¹

	Prepara- tion.	Cultiva- tion.	Harvest- ing.	Total.	Yield.	Cost.
					<i>Bushels.</i>	
Boy 1.....	18	16	20	54	56	\$17.40
Boy 2.....	22½	25½	8	56	59½	26.23
Boy 3.....	19	26½	30	75½	80	40.37
Boy 4.....	9½	5	15	29½	74	22.53
Boy 5.....	10	10	20	40	67½	15.00
Boy 6.....	35	39	16	90	67	32.10
Boy 7.....	25	24	40	89	97	30.25
Maximum.....	38	66	40	105	97	54.15
Minimum.....	7½	5	8	20½	43	15.00
Average.....	18	24	16	58	70	34.00

¹ Fields producing over 100 bushels not included in this list. Seven representative records were selected from 32 typical projects.

In Alabama 200 reports for the season of 1914 show an average of 63.9 hours of boy labor producing an average crop of 60 bushels.

Records of Oklahoma members show for 10 cotton records an average of 97 hours labor per acre; highest, 116 hours; lowest, 76 hours; for 9 corn records, average 42 hours; maximum, 58 hours, minimum, 26 hours; for 5 Kafir records, average 30 hours; maximum, 42 hours; minimum, 19 hours.

Louisiana averages for 10 corn-club members show, hours, 52.5; yield, 91.9; cost, \$24.60; age, 16.1; for 10 canning-club members, hours 58.3; yield, 78.60; cost, \$22.47; age, 17.

TABLE 20.—*Garden-club records from Texas.*

	Prepara- tion.	Growing.	Gather- ing.	Canning.	Total.	Yield of tomatoes.
						<i>Pounds.</i>
Girl 1.....	3½	23	23	10	59½	2,324
Girl 2.....	3¼	21	5	15	44½	1,246
Girl 3.....	3	4½	9½	10½	27½	1,700

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BULLETIN No. 386

Contribution from the Office of Public Roads and Rural Engineering

LOGAN WALLER PAGE, Director



Washington, D. C.

September 11, 1916

PUBLIC ROAD MILEAGE AND REVENUES IN THE
MIDDLE ATLANTIC STATES, 1914.

A Compilation Showing Mileage of Improved and Unimproved Roads; Sources and Amounts of Road Revenues; Bonds Issued and Outstanding; and a Description of the Systems of Road Administration and Fiscal Management, and of other Factors Affecting Road Improvement in Each State.

Prepared Jointly by the Division of Road Economics and the State Collaborators of the Office of Public Roads and Rural Engineering.

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INTRODUCTORY.

Beginning with 1904, the policy was adopted by the Office of Public Roads of conducting investigations at five-year intervals to determine the mileage of improved and unimproved roads, the revenues for road purposes, and other related data. In accordance with that policy, Bulletin No. 32 was issued, giving such information as was obtainable for the calendar year 1904, and Bulletin No. 41 was issued, giving such information as was available for the calendar year 1909. The investigation made for the year 1914 followed somewhat different lines, since a closer cooperation with State highway departments had been established, and wherever practicable the information was directly collected by collaborators named by the respective State highway departments and acting under specific instructions from this office. This policy was not practicable in connection with the earlier bulletins, owing to the fact that many of the States have only recently established highway departments.

NOTE.—This bulletin is of interest to all users of public roads and those who are concerned with road maintenance.

For convenient reference the information obtained from the Middle Atlantic States of New Jersey, New York, and Pennsylvania is published in this bulletin, leaving the remaining States to be dealt with by groups in subsequent similar publications. These groups have been selected according to their administrative organization for road purposes and according to other conditions affecting road management.

In order that the statistics may be useful in the highest degree, an explanatory text has been prepared for each State. In connection with the explanation of these statistical tables, the systems of administration, the methods of financing road work, the physical conditions influencing road improvement, and the progress made in recent years in the construction of roads and bridges, are set forth in the explanatory chapters.

WORKING PLAN AND SOURCES OF INFORMATION.

The method of procedure followed in obtaining the information contained in this bulletin was as follows:

A series of card-inquiry forms, designated A, B, C, and D, covering respectively mileage, taxation and revenues, administrative organization, and bond issues, was prepared and submitted to the various State highway departments for suggestion and approval. After changes were made to meet conditions found to be peculiar to the individual States, supplies of the card forms, with necessary stationery, were sent to each State collaborator, and correspondence was then conducted under Government frank with the respective county and township officials by the collaborators. In many instances it was impossible for the collaborators to obtain replies from all local officials, and accordingly letters and forms were sent directly from this office to such local officials. During the course of the investigation it was found necessary to enlist the aid of local and State road associations, chambers of commerce, automobile clubs, postmasters, and private individuals in order to obtain adequate information. On account of the absence of detailed records in many of the towns and counties, extreme accuracy is impossible, and because of the large amount of correspondence necessary to conduct the investigation, considerable delay in the issuance of the bulletins has been unavoidable. The data on mileage and revenues should therefore be considered as approximate only.

A summary sheet for each of the forms A, B, C, and D was prepared for each State at the outset of the investigation, and as the card forms were received from local officials or from the State collaborators, the information was entered on the summary sheets under appropriate headings. These summaries, when completed, were forwarded

to the respective State collaborators or to the heads of the State highway departments, who thereupon prepared a text explanatory of the statistical tables and of the administrative systems in effect in their respective States, or approved a text prepared in this office.

ROAD ADMINISTRATION IN THE MIDDLE ATLANTIC STATES.

All of the Middle Atlantic States have highway departments and apply State funds to the aid of road improvement. This policy was inaugurated in New Jersey in 1892, in New York in 1898, and in Pennsylvania in 1903. In New York and Pennsylvania the construction and maintenance of all roads is in a measure under State control. New York has developed a rather highly centralized highway department, and, like Pennsylvania and New Jersey, has a comprehensive system of State highways, for the construction and maintenance of which State funds are appropriated.

PUBLIC ROAD REVENUES.

State road funds in New York were at first provided by direct appropriations and at the beginning of 1906 amounted to \$25,000,000. During that year, a \$50,000,000 State bond issue was authorized, and a second issue of \$50,000,000 in 1912. Of the total bonds authorized, \$65,000,000 were issued on authority of the legislature to the close of the year 1914. In New Jersey and Pennsylvania State funds are provided by direct appropriations from the State treasury. Aside from the State-aid funds a considerable portion of the revenues for roads is provided by taxes, levied by the towns in New York State, by counties and townships in New Jersey, and by townships in Pennsylvania. Approximately one-third of all expenditures are provided by local units in New York and about one-half in New Jersey and Pennsylvania.

Table 1 presents in condensed form the information assembled concerning road expenditures and road bonds for New York, New Jersey, and Pennsylvania:

TABLE 1.—*Road expenditures and road bonds, 1914.*

State.	Total expenditures, 1914.	Road bonds voted or outstanding to December 31, 1914.	
		County, town, and township.	State.
New York.....	\$23, 231, 964	\$11, 822, 088	¹ \$100, 000, 000
New Jersey.....	7, 208, 287	14, 011, 337	.....
Pennsylvania.....	10, 424, 580	27, 547, 659	.....
Total.....	40, 864, 831	53, 381, 084	100, 000, 000

¹ Of which \$65,000,000 was issued to Dec. 31, 1914.

An interesting comparison showing the average expenditure for roads and bridges in these three States per mile of road, per square mile of area, per 1,000 population, and per \$100 of assessed valuation for the years 1904 and 1914 is presented in Table 2. This average does not indicate the distribution of expenditures, as it includes both construction and maintenance. Accordingly there may be many miles on which little or nothing was expended. The average, however, indicates the comparative financial burden proportionate to mileage.

TABLE 2.—*Analysis of expenditures on various bases.*

State.	Per mile of road.		Per square mile of area.		Per 1,000 of population.		Per \$100 assessed valuation.	
	1904	1914	1904	1914	1904	1914	1904	1914
New Jersey.....	\$220.64	\$486.49	\$435.00	\$959.00	\$1,730.00	\$2,833.00	\$0.34	\$0.289
New York.....	77.05	292.60	114.00	467.00	790.00	2,549.00	.095	.208
Pennsylvania.....	48.98	113.86	109.00	232.00	770.00	1,360.00	.124	.205

ROAD MILEAGE, 1914.

The total road mileage in the Middle Atlantic States to January 1, 1915, was 185,770.84, of which 31,516.23 miles, or 16.9 per cent of the total, were surfaced. This does not include streets in incorporated cities and towns, except a few miles in New York and Pennsylvania where the State roads pass through the small towns and boroughs. By comparing these figures with former investigations in the same States, it appears that between 1909 and 1914, 11,942.80 miles, or 6.4 per cent of the total, were surfaced. Table 3 summarizes all of the available information concerning road mileage for the three States.

TABLE 3.—*Road mileage, 1909 and 1914.*

State.	Total road mileage.	Miles surfaced.	Miles surfaced from 1909 to 1914.	Percentage surfaced.		Increase over 1909.
				1909	1914	
New York.....	79,398.00	15,635.90	2,848.9	16.13	19.6	<i>Per cent.</i> 3.5
New Jersey.....	14,817.00	5,897.45	2,475.9	22.76	39.8	17.0
Pennsylvania.....	91,555.84	9,982.88	6,618.0	5.84	10.9	7.0
Total.....	185,770.84	31,516.23	11,942.8	14.91	16.9	6.4

A diagram (fig. 1) shows the percentage of surfaced roads for these States at the close of the years 1904, 1909, and 1914. This diagram shows in a striking manner the strides which have been made during the past 10 years in road construction in these States.

The total mileage of roads and the surfaced mileage in relation to the square mile of area and 1,000 population for the years 1904, 1909, and 1914 are shown in Table 4.

TABLE 4.—*Analysis of mileage on various bases.*

State.	Total mileage.						Surfaced mileage.					
	Per square mile area.			Per 1,000 rural population.			Per square mile area.			Per 1,000 rural population.		
	1904	1909	1914	1904	1909	1914	1904	1909	1914	1904	1909	1914
New Jersey.....	1.97	1.97	1.97	26.74	23.6	23.5	0.32	0.45	0.784	4.4	5.4	9.4
New York.....	1.54	1.67	1.66	37.44	41.1	41.2	.12	.268	.328	2.98	6.6	8.1
Pennsylvania.....	2.21	1.95	2.22	34.9	28.8	30.17	.048	.075	.22	.76	1.11	3.29

DEVELOPMENT OF NEW TYPES OF HIGHWAY.

On account of the rapid increase in motor-vehicle traffic and the fact that more study is being devoted to the selection of types best adapted to traffic needs, the types of road surfaces have undergone considerable changes during the past 10 years. To illustrate this

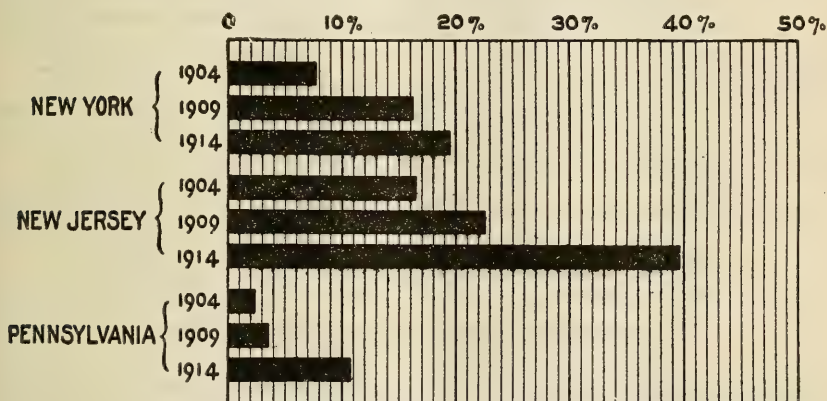


FIG. 1.—Percentage of surfaced roads in New York, New Jersey, and Pennsylvania for the years 1904, 1909, and 1914.

point it may be stated that of the 10,485 miles of surfaced roads in the Middle Atlantic States in 1904, approximately 60 per cent was plain macadam and 40 per cent was gravel. In 1909, of the 19,532 miles of surfaced road, 51 per cent was macadam, 47 per cent gravel, 1 per cent bituminous macadam, and 1 per cent other materials. In 1914, however, of a surfaced mileage of 24,482, 39.3 per cent was macadam, 36.3 per cent gravel, 15.4 per cent bituminous macadam, 3.8 per cent brick and concrete, and 5.2 per cent of other materials. It should be stated, however, in this connection that the 24,482 miles do not represent the total mileage of surfaced roads in 1914, as in the case of Pennsylvania it was impossible to secure detailed information regarding the type of surfaced roads in second-class townships. The decrease in the percentage of macadam roads from 51 per cent

in 1909 to 39.3 per cent in 1914 was due to the fact that many of these roads have been surface-treated and are now classed as bituminous macadam or bituminous-treated roads.

Of the 11,942.8 miles surfaced from the close of 1909 to the close of 1914, 9,629.82, which excludes second-class township roads in Pennsylvania, are classified as follows: 3,539.15, or 37 per cent, were treated with bitumen in some form; 1,992.75, or 20.5 per cent, were plain macadam; 2,501.32, or 26 per cent, were plain gravel; 485.95, or 5 per cent, were brick or concrete; and 1,110.65, or 11.5 per cent, were of other materials. This indicates conclusively that in the sections of country where heavy automobile traffic prevails, the old standard type of waterbound macadam has had its day.

Detailed information on the mileage of improved surfaces, by years and States, is shown in Table 5.

TABLE 5.—*Percentage by types of surfaced-road mileage.*

State.	Year.	Macadam.	Gravel.	Bituminous.	Brick.	Concrete.	Other materials.
New York.....	1904	37.2	62.8	-----	-----	-----	-----
	1909	36.1	63.9	-----	-----	-----	-----
	1914	38.0	37.1	20.0	1.0	1.6	2.2
New Jersey.....	1904	78.4	17.2	-----	-----	-----	-----
	1909	76.8	17.0	6.2	-----	-----	-----
	1914	30.7	48.5	7.0	-----	4.3	9.5
Pennsylvania.....	1904	100.0	-----	-----	-----	-----	-----
	1909	82.1	13.0	-----	-----	-----	4.9
	1914	¹ 63.9	¹ 7.9	¹ 6.7	¹ 9.1	-----	² 12.4

¹ State highways only.

² Concrete, stone block, flint, and stone.

DETAILED INFORMATION BY STATES.

Detailed information regarding sources and amounts of revenues, bonds issued and outstanding, mileage of improved and unimproved roads, systems of administration, and other factors affecting road improvement are presented in the following chapters for New York, New Jersey, and Pennsylvania, respectively.

NEW JERSEY.

By E. M. VAIL, *U. S. Collaborator.*

New Jersey is one of the most thickly populated States in the Union and consequently has more wealth and more miles of roads to the square mile of area than most of the other States where towns and cities and their connecting highways are of more recent construction.

The first roads of New Jersey were merely bridle paths or Indian trails. These were crooked and circuitous, and as the years passed they were widened with the increasing westward trend of settlement

and became in the end the foundation of the present-day system of highways. It was not until 1676 that any attention was given to the proper construction and maintenance of roads. As the State was all apportioned when the Government took up the town, township, and section method of laying out public lands, nothing was done in this line in New Jersey. In the early days private companies built turnpikes, many of which were laid straight without regard to grade. Consequently, the rebuilding of these roads in recent years so that they will be wide and straight, with good grades, has been a heavy expense.

The first public work on roads appears to have been conducted by local committees and gave rise to the general practice of working out the poll tax. This system of working out poll tax, however, has been abandoned during recent years.

In the county of Essex a small amount of county road work appears to have been done about 1868 to 1870. Nevertheless, the inhabitants of New Jersey traveled mostly on township roads until a general movement for county roads began in Union County in 1888.

New Jersey holds the distinction of being the first State to adopt the policy of State aid. The first State-aid work was done in 1892, and the first appropriation for State aid was \$75,000. At first the State paid $33\frac{1}{3}$ per cent of the cost of State-aid roads, but at present it pays 40 per cent. Up to July 1, 1914, the total outlay by the State aggregated \$5,800,000 and 1,833 miles of State-aid roads had been completed.

The collection of road mileage statistics and its division into classes was made under the direction of the division highway engineer, acting as United States collaborator, who was assisted in his work by other employees of the department of public roads of New Jersey and by county engineers and other county officials. The data upon which the expenditure and bonding tables were compiled were furnished by the office of the comptroller of the treasury of New Jersey, and the tables were made up from these data by employees of the Office of Public Roads and Rural Engineering.

Maps were obtained of all sections of the State and the length of the roads scaled by the State collaborator. Where these lengths were later checked by actual measurement, the results were very close. From most of the counties the engineers furnished accurate information of the work under their charge. In a few cases the townships had these data, but in most cases the best posted citizens indicated on the roads of their districts the general class and quality of pavement, if any, upon which the estimates for each township were based. In a few townships, however, the classes of roads had to be averaged with the classes of the adjoining townships. In order to complete the total mileage figures of roads and streets,

similar information was also obtained from the cities, boroughs, and other municipalities. This shows a total mileage of 20,445.

New Jersey has an area of 7,414 square miles of land and 710 square miles of water, making an average of 2.72 miles of roads per square mile of area. The State is divided into three belts—the northwestern or hilly country, from which trainloads of dairy products enter the large cities each day; the central, or marl belt, from which comes the name “Garden State”; and the southern, the flat sandy region formerly considered the pine barrens, though by the introduction of drainage and overhead irrigation in late years it has become a rich farming and trucking region. As this section is near the large cities of New York and Philadelphia, it has excellent markets.

Few people not residing close to the large cities will realize the additional cost, not only of construction but of maintenance, which is required to keep in repair roads carrying a traffic of, say, 2,000 vehicles or 6,000 tons daily. They wonder that a State as small as New Jersey should have so large a mileage of roads, constructed and maintained at so great an expense. This is explained by the fact that it lies between New York and Philadelphia, the two largest cities on the Atlantic seaboard, and is composed largely of suburban homes and manufacturing districts contiguous to these cities. New Jersey itself contains several large manufacturing cities.

In 1914, according to State registration, there was an average of 1 automobile for every 40 population and 6 automobiles for every mile of road. This heavy traffic is a severe tax on the roads, and it will, therefore, be seen that the cost of maintenance is necessarily large. Also, there are a number of motor-vehicle manufacturing concerns in New Jersey. When it is taken into consideration that every new vehicle must be tried out on the roads, it will be seen that this is an additional tax on their ability to sustain the traffic. This is especially true of the heavy motor trucks.

Some of the manufacturing cities of North Jersey are connected by roads constructed over the tide marshes. These roads have been under construction for a period of 100 years or more. The first step was to form corduroy out of the logs and branches of trees. Later planking was resorted to, and in recent years from 4 to 6 feet of earth and cinders have been filled in on top. Owing to the fact that these are practically pontoon roads, much of the material sinks below the surface of the water, or shoves out to the sides, so that perhaps 3 yards must be furnished for an apparent gain of 1 yard of fill. Upon this fill are constructed the most expensive types of pavement. Some of these roads are now so solid that they are carrying two lines of street cars, wide carriageways, and sidewalks.

The East Jersey coast forms an almost continuous chain of residential sections and pleasure resorts. This vast playground is fast becoming an all-year-round resort. As the surf bathing is one of the chief attractions, many cities are built on the low bars of sand which have been thrown up by the violence of the sea. Behind these bars are swampy sections and inlets. Roads across these sections are frequently built on fills many feet in depth, composed of material dredged from nearby streams and waterways. In order to form a solid roadway the original work is quite wide and the amount of material required to fill one of these roads is a mere conjecture. The slopes are frequently protected by sod or are planted with tufts of coarse grass.

What are known as sand-clay roads in New Jersey are constructed of second-quality gravel, engine cinders, or some other local product not listed in the standard specifications. These roads cost about \$1,000 a mile for grading and another \$1,000 for surfacing, or about \$2,000 per mile. Many of these roads are only paved for a width of 12 feet. Gravel roads, however, are from 14 to 40 feet in width and cost from \$2,500 to \$10,000 per mile.

Macadam roads in New Jersey are seldom less than 12 feet in width and 3 or 4 inches deep. In the wealthier districts they are 18 and 20 feet in width and from 8 to 12 inches deep, with 30 to 40 feet graded carriageways. They cost from \$5,000 to \$20,000 a mile, depending on the amount of grading and the depth of the pavement.

Asphalt macadam is seldom less than 16 feet in width, and in some cases it is as much as 60 feet in width. These roads cost from \$18,000 to \$125,000 per mile.

Block and brick roads in New Jersey are practically all laid on concrete foundations, and as they are almost always constructed where they are subject to the heaviest traffic, this class of road may be figured to cost not less than from \$40,000 to \$50,000 per mile.

While it is impossible to estimate exactly the cost of roads in New Jersey, the cost, based on the above figures, has, however, been roughly figured at a total of \$140,000,000.

EXPENDITURES.

The total expenditure for road and bridge construction and maintenance, and for interest and redemption of road and bridge bonds, for the year 1914 amounted to \$7,208,287. Of this amount \$3,542,572 was expended on State-aid roads for construction and maintenance, of which the State's share was \$1,306,596 and the share paid by the local units was \$2,235,976. State money available for expenditure during 1915 for construction and maintenance of State-aid roads amounted to \$1,360,000. From 1891 to January 1, 1915, the total

expenditure by the State for State-aid road construction and maintenance amounted to \$7,192,268. In 1904 the total expenditure for public roads amounted to \$3,274,811, of which the State's share was \$250,000. Thus in 1914 the total expenditures had increased 120 per cent as compared with 1904 and the State's share toward construction and maintenance increased 422 per cent. Information regarding expenditures is shown in detail by counties in Table 6.

TABLE 6.—*Expenditures on roads and bridges in New Jersey, 1914.*

[From townships report compiled from figures in annual report of comptroller of the treasury, 1914. Checked by New Jersey collaborator.]

County.	Expenditures on roads and bridges, 1914.			Interest and redemption on road and bridge bonds and notes.	Total expenditures.
	Road maintenance.	Road construction.	Bridges.		
Atlantic.....	\$109,760.32	\$15,611.35	\$41,541.91	\$40,030.00	\$206,943.58
Bergen.....	138,846.44	366,159.01	144,748.40	89,200.00	738,953.85
Burlington.....	10,378.63	82,282.94	60,743.78	35,199.43	188,604.78
Camden.....	29,979.94	80,101.07	65,576.53	44,935.11	220,592.65
Cape May.....	30,050.16	87,706.27	19,402.23	17,631.45	154,790.11
Cumberland.....	2,190.25	48,255.84	33,165.63	15,717.50	99,329.22
Essex.....	210,941.16	393,571.70	186,143.66	658,984.97	1,449,641.49
Gloucester.....	20,747.17	105,062.92	53,577.61	32,156.51	211,544.21
Hunterdon.....	16,844.04	176,538.21	32,025.50	8,317.00	233,724.75
Hudson.....	229,472.76	94,844.36	47,591.39	648,055.01	1,019,963.52
Mercer.....	86,448.16	156,590.21	51,563.35	48,387.25	342,988.97
Middlesex.....	86,097.01	93,347.97	60,813.57	90,149.68	330,408.23
Monmouth.....	111,055.88	139,271.12	116,767.54	7,395.66	374,490.20
Morris.....	133,171.08	105,225.63	30,856.40	12,000.00	281,253.11
Ocean.....	6,141.79	89,069.04	23,461.68	10,126.18	128,798.69
Passaic.....	133,455.37	193,675.62	40,020.04	58,640.48	425,791.51
Salem.....	7,500.00	47,175.44	53,813.55	7,000.00	115,488.99
Somerset.....	21,782.92	84,537.08	42,319.53	3,712.50	152,352.03
Sussex.....	6,263.04	105,868.44	9,138.48	7,004.00	128,273.96
Union.....	34,546.81	97,154.13	57,531.74	81,522.18	270,754.86
Warren.....	29,568.26	77,177.17	23,668.82	3,184.12	133,598.37
Total.....	1,455,241.19	2,639,225.52	1,194,471.34	1,919,749.03	7,208,287.08

According to the report of the comptroller of the treasury of New Jersey, the total county and township road and bridge bonds outstanding on November 30, 1914, amounted to \$14,011,337. Most of the bonds are deferred serial in character and the interest rates vary from 4 per cent to 5 per cent. Information showing the total bonds outstanding by counties and townships, with interest rates and the term of the bonds, is presented in Table 7.

TABLE 7.—*Outstanding road and bridge bonds, New Jersey, Nov. 30, 1914.*

County.	Township.	Bonds out- standing.	Rate of interest.	Fall due.
Atlantic.....		¹ \$402,000.00	<i>Per cent.</i> 4½ to 5	Various years up to 1957.
Bergen.....		1,679,000.00	3½ to 5	Various dates.
	Township of Over- peck and Ridge- field Park Vil- lage.	25,000.00		
	Franklin.....	5,500.00		Do.
	Hillsdale.....	42,500.00	5	Do.
	Midland.....	9,000.00	5	Do.
	Orvil.....	6,000.00	5	\$1,000 each year.
	River Vale.....	28,500.00	5	Do.
	Saddle River.....	75,000.00	5	A portion every 5 years.
	Union.....	42,500.00	4	1920.
	Washington.....	12,000.00	5	1934-35.
Burlington.....		74,322.76	4 to 4½	Various dates up to 1934.
	Chester.....	20,000.00	4½	Various dates.
	Lumberton.....	9,000.00	5	Various dates after 1916.
	New Hanover.....	27,000.00	4½	Various dates.
	North Hanover.....	14,000.00	4½	Do.
	Pemberton.....	29,000.00	4½	Do.
	Southampton.....	11,500.00	4½	Do.
	Willingboro.....	3,500.00	5	1 to 15 years.
Camden.....		464,100.00	4½ to 4½	20, 25, and 30 years.
	Gloucester.....	2,000.00	5	Various years.
	Haddon.....	1,200.00	5	Various dates.
	Voorhees.....	2,500.00	5	1920.
Cape May.....		355,500.00	4½ to 5	Various dates.
	Lower.....	1,500.00		1915.
Cumberland.....		¹ 204,000.00	5	Various dates after 1915.
	Downe.....	5,000.00	5	1924.
Essex.....		2,202,000.00	4½ to 5	
Gloucester.....		253,400.00	4½ to 5	1915 to 1939.
	Woolrich.....	2,600.00	5	1915 and 1916.
Hudson.....		4,261,672.00	4 to 4½	Various dates to 1964.
Hunterdon.....		318,000.00	4	30 years from date of issue.
	Bethlehem.....	2,492.58	5	1920.
	Kingwood.....	6,800.00	4	1917 to 1923.
	West Amwell.....	2,600.00	4½	1916 to 1923.
Mercer.....		555,150.00	3½ to 4½	1916 to 1944.
Middlesex.....		774,800.00	4 to 4½	1915 to 1949.
Monmouth.....	Neptune.....	17,000.00	4 to 5	1920.
Morris.....		280,000.00	4	
Ocean.....		36,000.00	5	1933.
	Long Beach.....	8,000.00	5	1922.
Passaic.....		879,500.00	4 to 5	1914 to 1931.
Salem.....		30,000.00	4	Various dates.
	Quinton.....	1,700.00	5	1915.
Sussex.....		196,100.00	4	1938 to 1944.
Union.....		600,000.00	4 to 4½	Sinking fund.
	Cranford.....	4,100.00	5	Various dates.
	Union.....	6,000.00	4½ to 5	1915 to 1920.
Warren.....		10,000.00	4	Various dates.
	Blairstown.....	5,000.00	4	1915 to 1919.
	Knowlton.....	2,300.00	5	Call.
	Mansfield.....	5,000.00	5	
Total.....		14,011,337.34		

¹ Partly for county buildings.

ROAD MILEAGE.

At the close of 1914 New Jersey had a total of 14,817.19 miles of public road, of which 5,897.45 miles, or 39.8 per cent, were surfaced. Of the surfaced roads 1,809.24 miles were plain macadam, 417.63 miles bituminous macadam, 2,858.52 miles gravel, 561.40 miles sand-clay, and 250.67 miles surfaced with other material, such as brick, concrete, asphalt concrete, stone, and asphalt block.

In 1904 New Jersey had 2,422.3 miles, or 16.32 per cent, of her total mileage surfaced. In 1909 she had 3,377 miles, or 22.75 per cent, of surfaced roads, while in 1914 she reports 5,897.45 miles, or 37.8 per cent of the total miles surfaced, thus showing that during the 5-year period 1909 to 1914, 2,475.99 miles of road, or 17 per cent of the total mileage, were surfaced. Information showing the total road mileage and mileage improved in the various counties is contained in Table 8, which does not include city streets. These are included in Table 9, which is supplementary and is given because New Jersey is, to a very great extent, urban in character, and the street and country-road problems are closely interwoven. Table 9 is copied from the Twenty-second Annual Report of the Commissioner of Public Roads, 1915.

TABLE 8.—*Mileage of all public roads in New Jersey, State and local, outside of incorporated cities, 1914.*

County.	Total mileage, all roads.	Surfaced roads.					Total surfaced roads.	Percent- age of all roads surfaced.	Increase or de- crease (—) in sur- faced road mileage over 1909.	Graded and drained earth roads.
		Macadam, plain.	Macadam with bitumen.	Gravel.	Sand clay (mixed).	Other hard-surfaced roads.				
Atlantic.....	806.86	1.54	.....	404.01	.....	11.31 bituminous concrete.	416.86	51.6	299.26	145
Bergen.....	435.45	176.97	6.60	.....	1.50	30.92 bituminous concrete, brick, and stone block.	215.99	49.5	—154.01	195.53
Burlington.....	1,368.35	87.60	79.40	108.30	48	4.10 bituminous concrete and cobble and 14.60 miles of shell.	342	25.2	83	199.50
Camden.....	546.56	53.49	.....	155.11	62	23.96 bituminous concrete.	294.56	53.9	114.99	41
Cape May.....	359	.....	.....	264	.....	.....	264	73.6	190.67	20
Cumberland.....	541	.....	.....	369	.....	.....	369	68.2	362.48	23
Essex.....	280.49	.....	24	.....	.....	21.55 bituminous concrete, stone block, and asphalt block.	244.19	87.0	—427.81	29.80
Gloucester.....	835.74	32.48	18.39	299.87	97	23 shell.	470.74	56.4	384.50	90
Hudson.....	74.43	24.72	15	.....	.....	28.61 bituminous concrete, brick, wood, stone, and asphalt block.	68.33	91.9	34.33	3
Hunterdon.....	990	85.87	30.03	.....	.....	.....	115.90	11.6	73.65	468.50
Mercer.....	474.22	140.46	19.26	.....	41.50	.....	201.22	42.4	—	259.50
Middlesex.....	677.39	164.01	16.19	65.66	.....	5.36 bituminous concrete, brick, and stone block.	251.22	37.1	53.88	398.58
Monmouth.....	1,271.08	64.95	1	619.13	172.70	.....	857.78	67.5	667.78	168.50
Morris.....	1,016.08	116.58	91.28	.....	.....	0.98 concrete and 0.24 brick.	209.08	20.7	46.64	420
Ocean.....	1,276.50	4.20	8	285.30	41	.....	338.50	26.5	270.50	496
Passaic.....	463.78	168.30	56.87	.....	.....	.....	225.17	48.6	—	212.61
Salem.....	659.56	4.50	1.99	285.137	97.70	42.865 shell and 0.775 concrete.	432.96	65.6	410.70	226.60
Somerset.....	725.60	233.50	4.50	.....	.....	.....	238	32.8	137.94	346.40
Sussex.....	976.63	52.65	22.38	1	.....	.....	76.03	7.8	46.03	536.80
Union.....	285.09	107.68	8.36	.....	.....	42.40 bituminous concrete, brick, and stone block.	158.44	55.6	—	80.90
Warren.....	753.38	91.10	14.38	2	.....	.....	107.48	14.2	42.66	382.40
Total.....	14,817.19	1,809.24	417.63	2,858.52	561.40	250.67	5,897.45	39.8	2,475.99	4,743.62

TABLE 9.—*Mileage of public roads, including city streets in New Jersey, in 1914.*

Name of county.	Roads.		City streets.					Estimated mileage.
	County roads.	Township roads.	Borough roads.	Town roads.	Village streets.	City streets.	Toll roads.	
Atlantic.....	153.86	653	30.25	180		236.65		1,253.76
Bergen.....	45.95	389.50	776.81		37.40	49.70	5	1,304.36
Burlington.....	215.90	1,152.45	14.75			41		1,424.10
Camden.....	97.56	449	102.29			349.36		998.21
Cape May.....	106	253	108.20			114.64		581.84
Cumberland.....	29	512	30.25			136.85	12	720.10
Essex.....	160.69	119.80	39.90	349.44	52	355.70		1,077.53
Gloucester.....	94.74	741	127.75			21.63	11	996.12
Hudson.....	42.80	31.63	9.10	126.34		287.67	4	501.54
Hunterdon.....	61.90	928.10	44.60	4		11		1,049.60
Mercer.....	150.72	323.50	33.03			136.20		643.45
Middlesex.....	238.04	439.35	126.60			130.47		934.46
Monmouth.....	220.89	1,050.20	221.70	13.10		100.20		1,606.09
Morris.....	152.08	864	79.70	66.64				1,162.42
Ocean.....	103.50	1,173	60.40					1,336.90
Passaic.....	203.14	260.64	75.01			212.82		751.61
Salem.....	68.01	591.55	18.66			16.20	6.40	700.82
Somerset.....	113.50	612.10	68.44	7				801.04
Sussex.....	39.83	936.80	34					1,010.63
Union.....	67.66	217.43	120.42	68.25		308.72		782.48
Warren.....	66.18	687.20	17	38				808.38
Total.....	2,431.95	12,385.25	2,138.86	852.77	89.40	2,508.81	38.40	20,445.44

Total for roads.....	Miles. 14,817.19
Total for streets.....	5,628.24
Grand total.....	20,445.44

NEW YORK.¹

New York, with a land area of 47,654 square miles, has 1.66 miles of road per square mile of area. According to the 1910 census 4,766,883 out of a total population of 9,113,614, or 52.3 per cent, lived in the city of New York, and the urban and rural population was, respectively, 7,185,494 and 1,928,120, or 78.8 per cent and 21.2 per cent, thus indicating the predominance of urban interests in the working out of the highway problem. There are 62 counties, varying in size from St. Lawrence, the largest, with an area of 2,880 square miles, to Schenectady, the smallest, with an area of 221 square miles. The counties of Bronx, Kings, New York, Queens, and Richmond are not considered in this report, as they are included within the city limits of New York City.

The topography of the State is varied and ranges from sand plains to low-lying granite mountains.

The good-roads movement in the State of New York dates back to 1898, when the Higbie-Armstrong law was passed. Under this law 50 per cent of the cost of highways was to be borne by the State, 35 per cent by the county, and 15 per cent by the towns through which the road passed. After completion, the roads were maintained

¹ S. D. Gilbert, auditor, and other members of the State highway department, rendered valuable assistance in the work for this State. The figures were checked by the United States collaborator at Albany, J. Burr Ryder.

under the supervision of the State engineer and surveyor at the expense of the towns. This method proved a failure, as the maintenance of various sections of a road depended on the wealth of the towns in which they were located and also on the efficiency of the respective town officials.

By the laws of 1913 the highway department was reorganized under a single head in lieu of the commission which had included other State officers as members. The State commissioner of highways is appointed by the governor, by and with the advice and consent of the senate, for a term of 5 years. He has general supervision of all highways and bridges which are constructed, improved, or maintained in whole or in part by State money. His salary is fixed by the governor at not to exceed \$10,000 per annum. He appoints three deputies, a secretary, nine division engineers, and all necessary assistant engineers and clerks.

The organization of the department is as follows: Commissioner, first deputy commissioner, second deputy commissioner, and third deputy commissioner, secretary, and auditor.

The law makes the commissioner responsible for all expenditures of the department and the proper execution of each contract. The State is divided into nine divisions, each under a division engineer in charge of the construction and maintenance of such road work as comes under the supervision of the State highway department. The highway department has under its supervision over 79,000 miles of road.

The highway improvement bonds were authorized in two amounts of \$50,000,000 each in 1906 and 1912, respectively. The term of these bonds is 50 years. Of the \$100,000,000 authorized, \$65,000,000 have been sold. The amount derived from the sale of State bonds is fixed by the legislature. For the year 1914, \$10,000,000 worth of State bonds were sold.

There are two classes of funds used for highway work. One is deposited with the State treasurer and is subject to the comptroller's check; the other is deposited with the county treasurer. The former, known as the highway improvement fund, is obtained from the sale of highway improvement bonds and the latter, called the general fund, is appropriated from the revenues of the State.

The highways of New York State are grouped in four classes, as follows: State highways, county highways, county roads, and town highways. The State and county highways together constitute the State system, and the town highways belong to the class of local roads which are aided and supervised by the State. The State has no supervision over county roads. State highways are those built at the sole expense of the State. They consist of about 3,800 miles of road on 45 routes prescribed by the legislature. The construction of these

highways is paid for from the proceeds of the sale of the State highway bonds. The maintenance is under the highway department, but is paid for by both the State and the towns through which they pass.

County highways are those built at the expense of both the State and county. These serve as the principal market routes within the counties. The State highway commissioner has designated 8,380 miles of these roads for the State. The total amount of State and county highways is nearly 12,000 miles. The State's share of the construction cost of county highways is paid from the appropriation made by the legislature from the fund derived from the sale of State highway bonds. The counties pay variable proportions of the cost of these roads and the balance is paid by the State. County highways are maintained in the same manner as State highways.

County roads are built at the sole expense of the county and are subject to the jurisdiction of the county officials. Inasmuch as the State grants aid for the maintenance of these roads, they are to a certain extent subject to the regulations of the State highway department. These roads are maintained from funds appropriated for this purpose, aided by a grant from the State's general fund amounting to 50 per cent of the county appropriation of the previous year for this purpose. However, no county receives from the State for this purpose in any one year an amount to exceed one-tenth of 1 per cent of the total taxable property in the county. Town highways are all roads outside of the limits of incorporated villages and cities which do not belong to the State and county system or to the county road systems. They are maintained and constructed by a joint State and town fund. When a town desires to secure State aid, it levies a money road tax for such amount that when it is added to the contribution made by the State it will equal not less than \$30 per mile for all roads outside the limits of incorporated villages and cities. For towns having a valuation of less than \$3,750 per mile there is a lower requirement, which is \$4 per thousand of assessed value. The amount which a town may receive from the State is regulated both by the appropriation of the town and its wealth per mile of road.

The bureau of town highways, which is under the third deputy commissioner, supervises the maintenance and construction of all town highways and bridges, and audits the road accounts in every town which receives State aid. At present it has 73,000 miles of road under its supervision. Of these roads 9,000 miles are of heavy gravel or macadam, and construction of these types is progressing at the rate of about 800 miles a year. Seven-tenths of the agricultural products of the State are moved over the town highways. This bureau also does educational work through annual meetings held in each county.

A county superintendent is elected in each county by the county board of supervisors. His term of office is for 4 years and his salary and expenses are paid from county funds. If the county fails to act, the State highway commissioner may make the appointment and have the expenses paid by the State in the first instance and reimbursed by the county. The county superintendent is appointed from a civil service list of eligibles and may be removed by the State highway commissioner for a specific cause. He has charge of all road and bridge work in the county, subject to the general control of the State highway department, and is required to furnish the town superintendents with such plans or other aid as they may require. He inspects all roads once a year.

The office of town superintendent is established in every town. The town superintendent may be elected either by the town or he may be appointed by the town board. The only qualification required of him is that he be a resident of the town. The term of his office is 2 years. He is in direct charge of the maintenance and construction of all town roads and bridges subject to rules and regulations of the State highway department.

The State highway department has a bureau of research for the testing of all road-building materials. The laboratories are well equipped and a large amount of work is done by this bureau. Stone tests conducted by the bureau of research totaled 909 during the calendar year 1914; of gravel and sand 956 tests were made. The bureau tested 1,238 samples of cement and 416 samples of brick. Tests of bituminous materials amounted to 1,330, and of cubes of concrete to 1,506.

EXPENDITURES, 1914.

The total expenditure in 1914 for construction and maintenance of all roads and bridges amounted to \$23,231,964 and included the following items: Expenditures by the State for construction of State and county highways, \$8,363,049; by the counties for construction, \$1,364,934; by the villages for construction of State and county highways, \$1,185,248; by the State for maintenance of State and county highways, \$3,837,727; by the State and towns for town roads, \$8,113,303; by the State for the maintenance of county roads, \$117,700; and by counties for maintenance of county roads, \$250,000. The expenditures are shown in detail by counties in Table 10.

In 1904 the total expenditure for roads and bridges amounted to \$5,692,514, including \$1,056,460 contributed by the State. During the 10-year period, therefore, from 1904 to 1914 the expenditures increased 308 per cent.

TABLE 10.—*Expenditures on roads and bridges for New York, 1914.*

	Total expenditures.	Expended by State for construction.	Expended by county for construction.	Expended by village for construction.	Expended by State for maintenance.	Total amount received for all town highway purposes. ¹
Albany.....	\$457,571.14	\$97,737.48	\$34,708.88	\$8,697.73	\$207,618.05	\$108,795.00
Allegany.....	558,101.92	266,386.74	23,736.94	40,823.99	41,308.62	185,845.63
Broome.....	339,610.40	148,608.21	6,286.06	1,808.15	66,445.15	116,462.83
Cattaraugus.....	392,363.29	166,724.87	1,626.77	29,482.76	18,795.78	175,733.11
Cayuga.....	387,209.08	85,209.02	41,949.16	1,390.39	72,137.56	186,522.95
Chautauqua.....	374,068.02	132,226.82	30,723.58	10,975.64	11,724.14	188,418.34
Chemung.....	349,845.98	136,302.87	30,652.97	77,070.84	34,164.32	71,654.98
Chenango.....	326,190.92	111,191.66	2,616.71	24,343.03	73,865.08	114,174.44
Clinton.....	251,836.14	88,708.90	3,600.00	10,636.47	64,236.51	84,654.26
Columbia.....	277,530.73	68,360.15	36,922.22	.....	45,127.31	127,121.05
Cortland.....	190,206.39	87,874.74	.....	6,308.82	34,985.87	61,036.96
Delaware.....	562,432.43	364,390.44	4,615.27	1,411.34	21,580.82	170,434.56
Dutchess.....	396,862.43	80,185.09	18,000.00	26,838.75	95,514.02	176,324.57
Erie.....	1,006,126.26	364,753.04	78,708.12	53,131.13	262,620.04	246,913.93
Essex.....	397,318.08	167,897.28	41,700.00	.....	46,349.43	141,371.37
Franklin.....	² 461,428.90	170,080.82	43,841.78	.....	60,103.60	169,902.70
Fulton.....	181,409.38	17,916.00	11,685.91	37,821.73	62,160.80	51,824.94
Genesee.....	270,859.57	68,337.09	.....	68,279.41	23,844.02	110,399.05
Greene.....	234,846.87	92,305.27	9,681.45	2,825.95	35,041.64	94,992.56
Hamilton.....	154,258.49	55,937.71	2,100.00	.....	33,766.29	59,454.49
Herkimer.....	369,914.15	105,564.60	12,088.26	9,459.45	108,015.63	134,786.21
Jefferson.....	¹ 1,106,124.48	559,100.95	167,982.33	46,551.02	132,126.90	200,363.28
Lewis.....	237,184.53	56,647.20	4,063.05	3,470.37	34,468.12	138,535.79
Livingston.....	393,737.80	153,733.48	.....	40,996.91	30,935.71	168,071.70
Madison.....	243,057.75	102,789.49	3,128.90	.....	14,163.37	122,975.99
Monroe.....	615,824.41	157,748.99	65,047.64	19,391.10	175,261.81	198,374.97
Montgomery.....	248,257.97	41,048.97	20,463.85	58,651.57	46,624.83	81,468.75
Nassau.....	³ 560,270.88	1,778.38	2,024.87	.....	48,356.12	181,911.43
Niagara.....	542,677.16	275,706.65	76,389.57	30,390.85	56,450.43	103,739.66
Oneida.....	890,249.42	462,923.68	53,773.66	33,684.78	146,369.20	193,498.40
Onondaga.....	502,675.62	147,378.64	60,216.38	8,572.83	153,147.01	173,360.56
Ontario.....	353,026.42	92,245.88	11,948.36	12,335.93	95,961.08	140,535.17
Orange.....	427,473.75	57,593.79	15,943.75	.....	174,409.77	479,526.44
Orleans.....	393,022.50	219,475.18	.....	39,074.59	44,289.60	90,183.13
Oswego.....	397,280.64	145,148.18	23,145.61	26,704.49	75,089.37	127,192.99
Otsego.....	397,156.23	173,306.23	6,346.34	2,998.44	81,809.09	132,693.13
Putnam.....	⁴ 105,631.58	34,530.35	.....	.....	21,004.30	48,596.93
Rensselaer.....	576,134.13	202,333.79	84,773.45	64,372.70	136,384.82	88,269.37
Rockland.....	⁵ 178,565.45	49,387.00	.....	.....	38,150.83	68,527.62
St. Lawrence.....	959,139.98	412,973.21	92,173.65	58,126.59	83,969.75	311,896.78
Saratoga.....	390,216.76	41,748.29	11,105.77	8,185.39	97,285.54	231,891.77
Schenectady.....	258,251.30	112,244.11	13,395.70	21,763.08	65,318.73	45,529.68
Schoharie.....	252,467.80	133,328.17	.....	9,728.01	9,937.19	99,474.43
Schuyler.....	123,109.33	56,706.67	5,917.82	7,617.91	8,772.23	44,094.70
Seneca.....	220,164.09	137,005.69	3,221.51	6,208.76	14,497.62	59,230.51
Stauben.....	764,981.80	387,783.43	29,848.64	23,804.95	86,968.59	236,576.19
Suffolk.....	772,154.58	161,168.13	7,200.00	2,618.47	70,160.79	531,007.19
Sullivan.....	250,462.24	61,639.95	.....	21,436.07	23,060.52	144,325.70
Tioga.....	226,562.73	126,428.48	.....	5,032.89	17,342.12	77,750.24
Tompkins.....	311,724.02	129,751.60	30,216.90	5,770.00	62,887.27	83,098.25
Ulster.....	387,031.30	61,732.38	43,074.26	17,271.34	103,065.00	161,888.32
Warren.....	179,819.29	51,333.62	16,300.00	.....	35,125.58	77,060.09
Washington.....	297,704.50	85,848.61	13,643.09	53,028.38	23,857.79	121,326.63
Wayne.....	284,890.63	95,325.99	17,623.11	2,868.98	25,859.38	143,213.17
Westchester.....	990,557.27	332,069.98	34,777.59	105,425.51	169,181.52	349,102.67
Wyoming.....	306,533.56	123,314.70	13,444.88	37,861.21	8,521.85	123,390.92
Yates.....	107,865.45	40,071.15	2,500.00	.....	7,509.44	57,784.86
Total.....	23,231,964.02	8,363,049.19	1,364,934.76	1,185,248.70	3,837,727.95	8,113,303.34

¹ Includes balance from previous year; amount collected and appropriated for roads by towns; amount received from State aid; amount collected and appropriated for bridges; purchase, repair, and storage of machinery and tools; removal of snow; and miscellaneous purposes.

² Includes \$11,000 appropriated by county and \$6,500 appropriated by State for county roads, 1914.

³ Includes \$223,000 appropriated by county and \$103,200.08 appropriated by State for county roads, 1914.

⁴ Includes \$1,000 appropriated by county and \$500 appropriated by State for county roads, 1914.

⁵ Includes \$15,000 appropriated by county and \$7,500 appropriated by State for county roads, 1914.

ROAD AND BRIDGE BONDS.

On January 1, 1914, according to Bulletin 136, United States Department of Agriculture, the various counties and towns of New York had voted \$11,729,088 road and bridge bonds, of which \$9,097,923 were county bonds and \$2,631,165 were town bonds. According to reports filed in the office of the State comptroller, \$93,000 of bonds were voted during the year 1914, \$33,000 in Albany County, and \$60,000 in Oswego County. The total county and town bonds voted to the close of 1914 appears, therefore, to be \$11,822,088. Of the authorized State bonds about \$10,000,000 are issued annually, and the money is used for the construction of State and county highways.

ROAD MILEAGE, 1914.

At the close of the year 1914, New York State had 79,398 miles of public roads. Of this mileage, 11,986.47 are classed as State and county highways. Of the State and county highways, 6,338.9 had been surfaced as follows: Bituminous macadam, 3,168.63; plain macadam, 2,354.97; gravel, 372.97; brick, 148.53; concrete, 244.19; and other materials, 49.61. In addition to this, 500 miles are classed as county roads, all of which were surfaced with macadam, bituminous macadam, and brick. Of the 72,555 miles of town roads, 3,363 were surfaced with macadam and 5,430 with gravel. Thus it appears that 15,635.9 miles, or 19.6 per cent of the total, were surfaced at the close of the year 1914.

In 1904 only 5,876 miles, or 7.96 per cent of the total, were surfaced, while in 1909, 12,787 miles, or 16.13 per cent of the total, were surfaced. Comparing the latter figures with those obtained for 1914, it appears that during the period 1909 to 1914 the State added to its surfaced roads 2,848.9 miles, or 3.5 per cent of the total.

Detailed information showing the total mileage of public roads and the mileage improved in the various counties is contained in Table 11.

TABLE 11.—*Mileage of public roads, State of New York, 1914.*

County.	Total mileage all roads in county.	State and county highways.						County roads.	Town roads. ¹
		Bituminous macadam.	Plain macadam.	Gravel.	Brick.	Concrete.	Other materials.		
Albany.....	1,098	58.00	121.24	.....	2.45	0.47	.....	182.16	915.84
Allegany.....	1,894	48.06	4.68	.....	2.73	15.20	² 7.91	78.58	1,815.42
Broome.....	1,437	68.845	61.887	.....	1.86	.....	.....	132.592	1,304.408
Cattaraugus.....	1,978	48.57	11.52	.....	.....	9.50	.....	69.59	1,908.41
Cayuga.....	1,490	55.07	45.67	.....	10	.....	.....	100.84	1,389.16
Chautauqua.....	1,950	17.76	4.104	.....	22.02	24.12	.....	68.004	1,881.996
Chemung.....	875	25.15	33.228	.....	5.47	.....	.....	63.848	811.152
Chenango.....	1,746	45.67	52.364	.....	6.35	.....	.....	104.384	1,641.616
Clinton.....	1,384	68.78	70.94	.....	.....	.....	.....	139.72	1,244.28
Columbia.....	1,379	56.75	24.29	6.67	.....	.....	.....	87.71	1,291.29
Cortland.....	1,037	24.54	50.17	.....	11	.....	.....	74.82	962.18
Delaware.....	2,358	100.33	14.70	1.00	.....	.....	.....	116.03	2,241.97
Dutchess.....	1,617	71.69	52.361	.....	.....	.....	.....	124.051	1,492.949
Erie.....	1,883	37.01	147.88	.....	53.93	20.69	.....	259.51	1,623.49
Essex.....	1,306	108.83	28.77	.....	.....	.....	.....	137.60	1,168.40
Franklin.....	1,367	61.82	14.92	.....	79	27	.....	77.80	³ 130 1,159.20
Fulton.....	769	36.33	25.05	.....	.....	.....	.....	61.38	707.62
Genesee.....	920	20.79	14.35	.....	27	.....	.....	35.41	884.59
Greene.....	1,062	69.96	4.48	.....	.....	.....	.....	74.44	987.56
Hamilton.....	444	35.74	14.18	.....	.....	.....	.....	49.92	394.08
Herkimer.....	1,454	31.85	74.22	.....	.....	2.41	.....	108.48	1,345.52
Jefferson.....	2,204	114.95	98.411	.....	58	3.01	.....	216.951	1,987.049
Lewis.....	1,448	56.57	4.58	.....	23	8.08	.....	69.46	1,378.54
Livingston.....	1,285	56.45	31.18	.....	.....	.....	.....	87.63	1,197.37
Madison.....	1,424	41.87	34.31	.....	.....	2.88	.....	79.06	1,344.94
Monroe.....	1,368	74.11	162.66	.....	12.26	3.25	.....	252.28	1,115.72
Montgomery.....	849	40.26	56.61	.....	.....	.....	.....	96.87	752.13
Nassau.....	1,491	28.745	14.99	.....	.....	6.58	.....	50.315	⁴ 287 1,153.685
Niagara.....	934	46.20	21.47	.....	16.73	26.96	.....	111.36	822.64
Oneida.....	2,317	93.70	112.86	.....	.....	3.43	.....	209.99	2,107.01
Onondaga.....	1,635	132.21	46.22	.....	76	6.7	.....	185.89	1,449.11
Ontario.....	1,348	42.40	80.13	246.06	61	18	.....	369.38	978.62
Orange.....	1,595	58.79	80.87	93.12	.....	.....	⁵ 8.76	241.54	1,353.46
Orleans.....	720	24.92	23.12	.....	2.59	18.17	.....	68.80	651.20
Oswego.....	1,714	76.65	21.86	7.31	.....	12.81	.....	118.63	1,595.37
Otsego.....	2,153	55.95	69.80	.....	47	.....	.....	126.22	2,026.78
Putnam.....	509	45.41	5.9	.....	.....	1.64	.....	52.95	⁶ 11 445.05
Rensselaer.....	1,291	75.09	80.19	12.39	.....	1.95	⁶ 3.15	172.77	1,118.23
Rockland.....	371	19.37	16.18	.....	.....	3.75	.....	39.30	⁶ 76 255.70
St. Lawrence.....	3,101	174.90	16.50	.....	1.25	.....	⁵ 3.89	196.54	2,904.46
Saratoga.....	1,521	57.76	41.82	6.06	1.00	.....	.....	106.64	1,414.36
Schenectady.....	1,413	31.56	24.91	.....	30	6.76	⁶ 11	63.64	349.36
Schoharie.....	1,259	14.81	18.68	.....	.....	8.98	.....	33.49	1,225.51
Schuyler.....	762	22.62	1.11	.....	.....	.....	.....	32.71	729.29
Steuben.....	3,094	94.48	42.79	.....	8.98	27	² 4.1 ⁶ 5.5	156.12	2,937.88
Seneca.....	704	36.59	6.75	.....	.....	70	.....	44.04	659.96
Suffolk.....	1,953	83.92	11.77	.....	.....	28.42	.....	124.11	1,828.89
Sullivan.....	1,844	45.98	16.07	.....	.....	.....	⁷ 8.34	70.39	1,773.61
Tioga.....	1,067	35.74	13.53	.....	1.63	.....	.....	50.90	1,016.10
Tompkins.....	1,091	47.60	44.98	.....	39	7.60	.....	100.57	990.43
Ulster.....	1,848	46.90	106.09	.....	1.17	.....	.....	154.16	1,693.84
Warren.....	1,010	53.97	37.63	.....	.....	.....	.....	91.60	918.40
Washington.....	1,533	48.35	19.23	36	.....	.....	.....	67.94	1,465.06
Wayne.....	1,348	36.94	15.11	.....	.....	11.85	.....	63.90	1,284.10
Westchester.....	908	104.22	92.67	.....	2.43	4.04	.....	203.36	704.64
Wyoming.....	1,069	32.88	.....	.....	.....	.....	² 7.85	37.00	1,032.00
Yates.....	769	24.22	12.99	.....	60	3.52	.....	45.53	723.47
Total.....	79,398	3,168.63	2,354.97	372.97	148.53	244.19	49.61	6,338.90	504 72,555.095

¹ Constant progress is being made in the matter of permanently improving town highways. At the close of the year 1914 there had been constructed a total of 3,363 miles of town macadam and 5,430 miles of gravel. All town roads, with the exception of about 2 per cent, have been improved in some manner.

² Slag.

³ Macadam.

⁴ Brick, bituminous macadam, and macadam.

⁵ Shale.

⁶ Earth.

⁷ Granite.

PENNSYLVANIA.¹

Pennsylvania, with an area of 44,832 square miles, has 2.22 miles of road per square mile of area, and a population, according to the census of 1910, of 7,665,111, which makes her the second largest State in the Union in point of population, while there are 33 other States having larger areas. It has 67 counties, varying in size from Center, the largest, with an area of 1,146 square miles, to Montour, the smallest, with an area of 130 square miles. Pennsylvania's topography is quite diversified, about one-fourth of the area being covered by hills and mountains. It has a number of large rivers, among which are the Schuylkill, the Susquehanna, the Monongahela, and the Allegheny.

Pennsylvania has a highly organized highway department, with offices located in the State capitol at Harrisburg. The organization of the department is as follows: Commissioner, first deputy, second deputy, chief engineer, construction engineer, auditor, statistician, automobile division registrar, chief clerk, engineer of tests, engineer of bridges, and chief draftsman. There are 15 assistant engineers in charge of the 15 districts into which the State is divided.

The State highway department is at present operating under what is known as the "Sproul Act." Under this act, 375 routes, containing approximately 10,200 miles, are designated as State highways. Toll roads included in State highways are purchased by the State. Contracts are awarded by the State highway department on plans and specifications prepared by the department. All State highways are improved to a width of 12 feet. The maintenance of the roads improved as State highways is taken care of by the State highway department, except that under certain conditions boroughs and incorporated towns through which State highways lie pay 50 per cent of the cost of maintenance.

Railways, railway crossings, gas or water pipes, and electric conduits are not allowed to be laid on State highways without permits. Neither may telegraph, telephone, electric light, or power poles be erected on such highways without special permission from the State highway department.

The department also is required to give aid in the improvement of certain roads which are not included in the State highway system. Under this provision of the law, counties and townships, by application, may receive from the State not to exceed 50 per cent of the cost of improvement of roads within the limits of such counties or townships, and for maintenance of such roads thereafter. The basis of apportionment of State aid to counties and townships is the mileage

¹ W. R. D. Hall, the statistician of the Pennsylvania highway department, rendered valuable assistance in this connection.

of highways in such units. These State-aid highways are maintained by the State highway department, and 50 per cent of the cost of such maintenance is repaid by the townships or counties in which the roads are situated.

In 1911, \$3,000,000 was appropriated under the Sproul Act for the maintenance, repair, and construction of State highways, and for the State's share of maintenance of State-aid highways. One million dollars was appropriated for the improvement of roads designated as State-aid highways.

The legislature of 1915 appropriated \$8,300,000 to the State highway department for the two years ending June 1, 1917. Of this appropriation \$6,000,000 is for the construction and maintenance of State highways; \$250,000 is for the purchase or condemnation of turnpikes which are included in the State highway system; \$500,000 is for the State's share in the construction and maintenance of State-aid highways; \$50,000 is for the repair and maintenance of the Old Cumberland Road, and \$1,500,000 is to cover a portion of the deficiency on the repayment of a cash-tax bonus to the townships for previous years. This repayment of the cash-tax bonus is a function of the bureau of township highways. The State highway department's care of this fund is merely custodial. Previously, money derived from motor-vehicle licenses had been given to the State highway department, in addition to the money appropriated by the legislature; but in the latter act of the legislature the following proviso is found:

Provided, That the appropriation made by this act shall include and not be in addition to the amounts received by the Commonwealth during the two fiscal years beginning June 1, 1915, for the licensing of motor vehicles and drivers, under the act of July 7, 1913.

Therefore, the money derived from motor-vehicle licenses is included in the appropriation of \$8,300,000, and is not in addition thereto.

In 1913 a bureau of township highways was established in the highway department, under supervision of one of the deputies, and has general supervision over all township and highway bridges on which State-aid money has been expended. The bureau also has charge of the administration of township highways through the various division engineers. The township supervisors report annually to the bureau of township highways relative to the number of miles of township roads and the money derived for road purposes through taxation. The bureau then grants each township 50 per cent of the total amount of road tax collected in the township, provided that no township shall receive in any one year to exceed \$20 per mile of township road. Work done in the townships under this law is in accordance with regulations prescribed by the State highway department.

There are 45 "first-class" townships which do not come within the jurisdiction of the bureau of township highways. A first-class township is one having a population of more than 300 to the square mile. Road work in these townships is under the supervision of boards of township commissioners, who have absolute control over all road work and the collection and expenditure of road funds within their respective townships. The majority of these townships are included within the limits of incorporated cities and boroughs, and consequently have no country roads.

A few of the counties also have what are known as county roads, which are improved and maintained solely at the expense of the counties in which they are located.

Bonds may be issued by counties or townships to secure funds for road improvement or maintenance. At present bond issues for road improvement can not be made by the State, but for some time efforts have been made to amend the constitution in this connection.

In 1911, and again in 1913, the legislature passed an amendment to the constitution permitting the State to issue \$50,000,000 in bonds for road improvement. The amendment was then brought before the people for ratification at the election in November of that year and was defeated by a majority of 40,000. Again, in 1915, the legislature passed an amendment and, as before, this will be passed upon by the next legislature, and if so passed it will be submitted to the people at the fall election in 1918. This procedure is in accordance with constitutional provisions.

EXPENDITURES, 1914.

It was impracticable to secure complete information regarding taxation and revenues from the various counties and townships in Pennsylvania. A summary of expenditures for the State as a whole, including expenditures in first-class townships, was, however, obtained from the State highway department and is as follows:

Expenditures by second-class townships.....	\$5, 500, 091
Joint funds, State, counties, and townships.....	2, 634, 205
Road work done solely at State expense.....	2, 290, 284

Total expenditures by State, counties, and townships.....	10, 424, 580
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In 1904 the total expenditures for public roads by the State, counties, and townships aggregated \$4,887,266, and the increase in 1914 as compared with 1904 was, therefore, 113.2 per cent.

ROAD AND BRIDGE BONDS.

On January 1, 1914, the various counties and townships had voted \$27,172,659 of road and bridge bonds, of which \$24,839,050 were county bonds and \$2,333,609 were township bonds. For the year

1914, reports were received from only one township and two counties, showing additional bonds voted. These were as follows:

Allegheny County, Shaler Township.....	\$25, 000
Lackawanna County.....	100, 000
Westmoreland County.....	250, 000
Total.....	375, 000

By adding these three issues to the total given above it appears that the total bonds voted up to and including the year 1914 aggregate \$27,547,659. Owing to the incomplete returns from counties and townships for 1914, it is impossible to say whether this includes all bonds voted.

ROAD MILEAGE, 1914.

In Table 12 it will be seen that at the close of 1914, Pennsylvania had 91,555.84 miles of public roads. Of this total, 10,235.5 miles were classed as State roads, 80,376.31 as second-class township roads, 583.87 as county roads not on the State highway system, and 164.08 as first-class township roads. The county roads and the first-class township roads are not included in the table, except in the total mileage column.

The portions of State highways passing through boroughs have been included in the table and are shown separately from other roads. While these highways lie within incorporated limits of boroughs, their construction and maintenance is by the State highway department, since they are the connecting links of these State highway routes which pass through the boroughs.

Of the State highways, 2,942.26 miles, or 28 per cent, were surfaced as follows: 1,881.8 plain macadam, 198.33 bituminous macadam, 269.33 brick, 235.19 gravel, and 367.6 with other materials, such as concrete, stone block, flint, and stone. Of the county roads, all were surfaced, making a total mileage of 583.87 not included among State highways. These are not shown in the table, but are distributed as follows: 485.72 miles in Allegheny County; 32 miles in Cumberland County; 26.8 miles in Lackawanna County; 2.12 miles in Lehigh County; 4 miles in McKean County; and 13.23 miles in Westmoreland County. Of the roads in first-class townships, not on State highways and not shown in the table, 46.75 miles are distributed as follows: 21.75 miles in Allegheny County and 21 miles in Montgomery County. Of the second-class township roads, it is estimated that about 8 per cent, or 6,430 miles, was surfaced with some kind of hard material. It thus appears that of the total mileage of all roads, 9,982.88 miles, or 10.9 per cent, were surfaced at the close of 1914.

In 1904 only 2,160.8 miles, or 2.17 per cent, of the total mileage, were reported as surfaced, while in 1909, 3,364.76 miles, or 3.84 per cent, were surfaced. It appears, therefore, from these comparisons that during the 5-year period 1909-1914, 6,618 miles, or about 7 per cent of the total mileage, were surfaced.

TABLE 12.—*Mileage of public roads, State of Pennsylvania, 1914.*

County.	Miles of public road.						Miles of State highways surfaced.					
	Total road mileage.		Total State highways.		Toll roads on State highways.		County roads on State highways.		Macadam.		Bituminous macadam.	
	County.	Borough.	County.	Borough.	County.	Borough.	County.	Borough.	County.	Borough.	County.	Borough.
Adams.....	1,221.24	16.23	140.22	16.23	16.85	3.29	7.87	1,078.02	42.78	11.10	1.61	15.60
Allegheny.....	2,620.86	24.83	136.11	24.83	10.47	7.93	82.54	1,265.28	7.40	4.58	6.38	4.26
Armstrong.....	1,815.72	12.74	138.42	12.74	4.77			1,677.30	7.40			3.91
Beaver.....	1,553.56	17.84	117.48	17.84				1,035.88	1.12			1.98
Bedford.....	1,942.39	9.27	237.99	9.27				1,704.40	42.35	5.96		8.88
Berks.....	2,498.50	20.85	194.11	20.85	13.00	2.18		2,295.39	106.92	15.19	4.34	.12
Blair.....	760.38	11.45	81.88	11.45	3.54	.43		678.50	48.55	3.07	5.05	.39
Bradford.....	2,552.42	18.35	177.18	18.35	19	6.79		2,375.24	14.34	3.73		6.29
Bucks.....	1,899.26	20.41	185.85	20.41	60.41			1,693.66	57.92	11.42	8.63	2.37
Butler.....	1,861.17	25.24	154.45	25.24				1,706.72	7.87		.84	.03
Cambria.....	1,210.36	24.54	140.96	24.54	3.64			1,069.40	14.57	1.56		6.46
Cameron.....	166.63	4.35	50.38	4.35				1,069.40	1.15	.48		1.28
Carbon.....	524.19	15.17	34.60	15.17				489.59	14.30	1.46	.08	.14
Center.....	1,223.25	10.47	214.04	10.47	7.93			1,003.71	40.02	2.96	1.17	1.91
Chester.....	2,560.41	25.70	262.50	25.70	4.77			2,297.91	130.79	20.66	14.99	.81
Clarion.....	1,410.98	15.53	127.10	15.53				1,283.88	4.57	.56	.60	2.28
Clearfield.....	1,755.78	30.25	145.40	30.25				1,610.38	10.18		2.02	6.58
Clinton.....	1,942.99	8.97	110.87	8.97				1,832.12	13.12	1.23		.99
Columbia.....	1,946.15	18.38	109.15	18.38			.38	1,237.00	11.01	2.20	.56	3.15
Crawford.....	2,263.57	17.43	198.64	17.43				2,064.93	14.81	1.00	.53	19.36
Cumberland.....	1,300.00	12.74	110.32	12.74				1,157.68	65.45	11.78	.44	1.31
Dauphin.....	1,995.90	18.64	101.72	18.64	5.00			1,894.18	32.88	14.68	3.81	.44
Delaware.....	347.67	16.80	85.59	16.80	14.68	5.35		262.08	47.25	5.64	2.66	.71
Elk.....	584.65	7.99	81.51	7.99				503.14	3.90			1.45
Erie.....	1,749.22	17.94	196.67	17.94				1,552.55	10.77	.58	3.50	2.32
Fayette.....	1,759.60	12.23	140.33	12.23				1,619.27	32.80	.88	11.03	3.92
Forest.....	374.80	2.46	73.30	2.46				301.50	82.80			8.67
Franklin.....	1,466.39	11.17	168.05	11.17	20.26	3.66		1,291.21	78.02	6.40	.68	2.00
											.33	.78

* Concrete.

* Stone.

* Stone block.

TABLE 12.—*Mileage of public roads, State of Pennsylvania, 1914—Continued.*

County.	Miles of public road.										Miles of State highways surfaced.													
	Total road mileage.		Total State highways.		Toll roads on State highways.		County roads on State highways.		Second-class township roads.	Macadam.		Bituminous macadam.		Brick.		Gravel.		Other materials.						
	County.	Borough.	County.	Borough.	County.	Borough.	County.	Borough.		County.	Borough.	County.	County.	Borough.	County.	County.	Borough.	County.	County.	Borough.				
Fulton.....	755.47	0.86	133.47	0.86	3.32						19.80	0.86												
Greene.....	1,522.78	5.51	103.88	5.51							5.95													
Huntingdon.....	1,484.97	11.49	204.62	11.49	2.18						49.25	3.57	4.36											
Indiana.....	2,072.22	14.00	194.97	14.00							17.10	.15												
Jefferson.....	1,321.79	20.51	137.53	20.51							2.42	.45	2.60											
Juniata.....	828.28	2.39	104.08	2.39							6.56	1.21	6.58											
Lackawanna.....	652.06	44.36	58.86	44.36	4.37	0.79					16.71	4.51	2.47	11.32										
Lancaster.....	3,074.49	19.69	229.57	19.69	70.67	3.03					27.60	12.46	3.68	.58										
Lawrence.....	897.30	6.03	79.17	6.03							5.57													
Lebanon.....	853.37	5.10	81.97	5.10	19.67						34.13	5.10												
Lehigh.....	1,175.56	4.48	71.36	4.48	3.37						15.19	3.66	4.86	1.2										
Luzerne.....	1,262.13	30.51	164.93	30.51							30.71	3.34		1.23	.51	15.95	33.24	1.91						
Lycoming.....	1,833.11	16.35	263.70	16.35							10.07	.22	8.24	.94	.55	4.55								
McKean.....	845.67	13.25	174.52	13.25							7.17		1.56			3.38								
Mercer.....	1,727.61	23.58	142.88	23.58							15.97	.09	4.62	.27		1.51	8.60							
Mifflin.....	535.75	4.85	77.76	4.85	3.80	1.29					18.47	1.60	4.38			1.96								
Monroe.....	1,018.90	9.55	139.44	9.55							36.59	6.52				.92	6.70							
Montgomery.....	1,721.49	27.18	202.47	27.18	55.32	6.77					118.64	17.47				.03	1.41							
Montour.....	355.93	2.47	31.67	2.47							5.71	.89												
Northampton.....	1,107.29	14.67	75.28	14.67							26.11	10.54		2.66		.04	4.43	1.12	34.10	3.37	3.29			
Northumberland.....	1,099.63	20.68	137.33	20.68							17.50	2.98	7.55			1.98	7.00	3.31	1.44					
Perry.....	1,065.06	11.22	126.28	11.22							6.15	6.23												
Pike.....	588.81	2.05	123.77	2.05							1.54		.74	.64										
Potter.....	1,126.90	13.27	140.49	13.27							6.70	4.20				1.58								
Schuylkill.....	1,348.90	30.61	132.57	30.61							30.86	13.72		1.00		6.05	20.74	3.25	18.42	3.35	1.34			
Snyder.....	795.88	2.52	82.35	2.52							3.59			.90		.28								
Somerset.....	2,253.74	15.65	192.28	15.65	8.13						*.51	*.30	*4.00											
Sullivan.....	582.23	5.97	101.60	5.97							31.69	2.24												

Susquehanna.....	2,142.05 ¹	18.58 ²	209.31	18.58 ²	.....	.....	1,932.74	7.02	1.27	6.36	1.85	1.35	8.86	2.40	.....
Tioga.....	1,905.53	21.81	168.13	21.81	.....	.....	1,737.40	14.60	3.30	.....	.....	4.61	.....	.....	.....
Union.....	544.66	4.91	70.86	4.91	.....	.....	473.80	7.51	1.04	3.43	.....	.14	.....	14.76	12.30
Venango.....	1,207.25	5.38	139.38	5.38	7.21	.....	1,067.87	1.75	.....	.....	.....	.49	.....	.....	.....
Warren.....	1,149.90	13.81	143.41	13.81	.....	.....	1,006.49	7.40	.....	4.27	.74	.30	3.82	.....	.....
Washington.....	2,298.30	43.21	185.50	43.21	.....	.....	2,112.80	* 5.14	* 1.04	9.45	.....	.09	23.44	.....	.....
Wayne.....	1,500.99	15.17	132.21	15.17	.....	.....	1,368.78	27.65	3.09	.....	.....	1.32	4.86	1.24	.....
Westmoreland.....	2,865.47	23.73	247.44	23.73	.....	.....	2,604.80	82.51	.01	.....	.....	.18	12.00	.....	.....
Wyoming.....	768.26	8.01	96.16	8.01	.....	.....	672.10	3.83	.99	.....	.....	.....	21.52	.11	.....
York.....	2,851.81	23.08	215.02	23.08	.....	.....	2,630.45	12.51	3.85	4.56	3.29	.39	.....	.....	.....
Total.....	90,551.38	1,004.46	9,231.04	1,004.46	.....	.....	80,376.31	1,630.82	250.98	164.22	34.11	45.68	223.65	215.24	19.95
Grand total.....	491,555.84	10,235.50	433.97	154.95	.....	.....	80,376.31	1,881.80	198.33	269.33	235.19	.....	.....	.....	.....

¹ Flint.² Stone.³ Concrete.

⁴ Includes mileage of toll roads not on State highways as follows: Adams, 3; Berks, 9; Bucks, 19.75; Center, 5.5; Franklin, 7.13; Huntingdon, 4; Lackawanna, 7; Lancaster, 75.63; Montgomery, 58.73; and York, 6.34; or a total of 196.08 miles.

⁵ Comprising 5.28 miles of stone block, 236.80 miles of stone, 11.69 miles of concrete, and 103.8 miles of flint.

* National road.

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UNITED STATES DEPARTMENT OF AGRICULTURE



BULLETIN No. 387



Contribution from Office of Public Roads and Rural Engineering
LOGAN WALLER PAGE, Director.

Washington, D. C.

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PUBLIC ROAD MILEAGE AND REVENUES IN THE SOUTHERN STATES, 1914.

A Compilation Showing Mileage of Improved and Unimproved Roads, Sources and amounts of Road Revenues, Bonds Issued and Outstanding, and a description of the Systems of Road Administration, Fiscal Management and other Factors affecting Road Improvement in Each State.

Prepared Jointly by the Division of Road Economics of the Office of Public Roads and Rural Engineering, and State Collaborators.

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INTRODUCTORY.

In 1904 the Office of Public Roads adopted the policy of conducting an investigation every five years to determine the mileage of improved and unimproved roads, the revenues for road purposes, and other related data. In accordance with this policy Public Roads Bulletin No. 32 was issued, giving such information as was obtainable for the calendar year 1904, then Public Roads Bulletin No. 41, giving such information as was available for the calendar year 1909. The investigation made for the year 1914 followed somewhat different lines, as a

closer cooperation was maintained with State highway departments, and wherever practicable the information was collected directly by collaborators named by the respective State highway departments and acting under specific instructions from this office. This policy was not practicable in connection with earlier bulletins owing to the fact that many of the States then had no organized highway departments.

For convenient reference and to avoid delay in publication, the information obtained from the Southern States is published in this bulletin. Bulletins on this subject covering the Middle Atlantic States and the New England States have been issued, and the Middle Western and Western States will be dealt with in a subsequent publication.

WORKING PLAN AND SOURCES OF INFORMATION.

The method of procedure followed in obtaining the information contained in this bulletin was as follows:

A series of card inquiry forms, designated A, B, C, and D, covering, respectively, mileage, taxation and revenues, administrative organization, and bond issues, was prepared and submitted to the various State highway departments for suggestion and approval. After changes were made to meet conditions peculiar to individual States, supplies of the card forms, with necessary stationery, were sent to each State collaborator, and correspondence then was conducted by the collaborators under Government frank with the respective county and township officials.

In many instances it was impossible for the collaborators to obtain replies from all local officials, and accordingly letters and forms were sent directly from this office to such local officials. In the course of the investigation it was found necessary to enlist the aid of local and State road associations, chambers of commerce, automobile clubs, postmasters, and private individuals in order to obtain adequate information. On account of the absence of detailed records in many of the towns and counties utmost accuracy is impossible, and because of the large amount of correspondence necessary to conduct the investigation, considerable delay in the issuance of the bulletins has been unavoidable. The data on mileage and revenues should, therefore, be considered as approximate only.

A summary sheet for each of the forms A, B, C, and D was prepared for each State at the outset of the investigation, and as the card forms were received from local officials or from the State collaborators the information was entered on the summary sheets under appropriate headings. These summaries, when completed, were forwarded to the respective State collaborators or to the heads of the State highway departments, who thereupon prepared a text explanatory of the statistical tables and of the administrative system in effect

in their respective States, or approved a text prepared in this Office. The bulletin is issued, therefore, in the form of a series of chapters, each under the authorship or approval of the State official who has cooperated with this Office in assembling the data.

ROAD ADMINISTRATION IN THE SOUTHERN STATES.

In 1914 four of the Southern States, namely, Alabama, Louisiana, Maryland, and Virginia, maintained State highway departments and applied State funds to road improvement. Delaware provided a State highway commissioner for New Castle County and appropriated \$10,000 to each county as State aid. Maryland has developed a rather highly centralized highway department, and not only aids the counties in road construction but also has spent considerable money in the construction of State roads, for which State bonds have been issued. In five of the Southern States, namely, Arkansas, Kentucky, North Carolina, Oklahoma, and West Virginia, State highway departments were in operation, but the work of the State highway departments related entirely to educational, advisory, and engineering assistance, except in the State of Arkansas, where \$75,000 was provided by the State for the purchase of a crushing plant to be operated by State prisoners. In North Carolina the educational and advisory work was carried on under the direction of the North Carolina Geological and Economic Survey. Georgia had no State highway department, but furnished State convicts for the purpose of building county roads. In five of the Southern States, namely, Florida, Mississippi, South Carolina, Tennessee, and Texas, no State highway departments had been organized and no contributions were made by the States toward local roads.

Since 1914, however, Florida, Mississippi, and Tennessee have established highway departments and Kentucky and Oklahoma have enlarged their highway departments and made provision for granting State aid to the counties. The legislature of Virginia in the early part of 1916 provided for the maintenance of all State roads under the direction of the State highway department. In most of the Southern States the great bulk of road work still is done under the direction of county authorities.

Detailed information as to the administration of public roads in each of the Southern States is given in the chapters which relate respectively to each State.

PUBLIC ROAD REVENUES.

The total revenues applied to roads and bridges in the Southern States in 1914 amounted to \$52,516,559.73, including State appropriations, amounts derived from local taxation, and expenditures from bond issues, both State and local. In 1904 the total revenues applied to this purpose amounted to \$21,590,682.29, thus showing

that during the 10-year period 1905 to 1914, inclusive, the revenues increased \$30,925,877.44 or 143.2 per cent. Table 1 presents in condensed form the information assembled concerning revenues for the Southern States for the year 1914, with comparative information for the year 1904.

TABLE 1.—*Revenues applied to roads and bridges, 1914.*

States.	Total revenues applied to roads and bridges.		Increase in revenues over 1904.	
	1914	1904	Total.	Percentage.
Alabama.....	\$3,949,019.00	\$1,576,434.27	\$2,372,584.73	150.5
Arkansas.....	1,522,696.20	1,395,342.80	127,353.40	9.1
Delaware.....	511,628.00	90,802.88	420,825.12	463.4
Florida.....	2,280,255.09	577,577.10	1,702,677.99	294.7
Georgia.....	3,688,172.25	2,080,872.33	1,607,299.92	77.2
Kentucky.....	2,474,621.00	2,148,689.03	325,931.97	15.1
Louisiana.....	1,777,572.12	951,872.86	825,699.26	86.7
Maryland.....	6,000,652.03	873,470.50	5,127,181.53	586.9
Mississippi.....	3,960,377.00	1,675,455.45	2,284,891.55	136.3
North Carolina.....	5,215,490.78	1,358,687.00	3,856,803.78	283.8
Oklahoma.....	2,112,680.80	774,775.59	1,337,905.21	172.6
South Carolina.....	1,024,480.37	745,701.50	278,778.87	37.4
Tennessee.....	2,370,560.16	1,621,777.15	748,783.01	46.1
Texas.....	9,920,079.11	4,138,157.49	5,781,921.62	139.7
Virginia.....	3,224,528.82	687,751.06	2,536,777.76	368.8
West Virginia.....	2,483,747.00	893,285.28	1,590,461.72	178.0
Total.....	52,516,559.73	21,590,682.29	30,925,877.44	143.2

An interesting comparison showing the average revenues for roads and bridges in the Southern States per mile of road, per square mile of area, per 1,000 of rural population, and per \$100 of assessed valuation for the years 1904 and 1914 is presented in Table 2. This average does not indicate, however, the distribution of expenditures, as between construction and maintenance.

TABLE 2.—*Relation of public road and bridge revenues to mileage, area, population, and assessed valuation, 1904 and 1914.*

States.	Revenues.							
	Per mile of road.		Per square mile of area.		Per capita.		Per \$100 of assessed valuation.	
	1904	1914	1904	1914	1904 ¹	1914 ²	1904 ³	1914 ⁴
Alabama.....	\$31.47	\$71.22	\$30.74	\$77.01	\$0.86	\$1.84	\$0.53	\$0.69
Arkansas.....	38.28	30.00	26.56	28.99	1.06	.96	.62	.36
Delaware.....	30.26	139.25	46.21	260.37	.49	2.52	.13	.545
Florida.....	33.24	126.71	10.52	41.56	1.09	3.02	.56	1.07
Georgia.....	36.37	45.72	35.43	62.80	.93	1.41	.44	.437
Kentucky.....	37.60	42.52	53.47	61.58	1.00	1.68	.30	.239
Louisiana.....	38.23	72.37	20.96	39.10	.68	1.073	.30	.322
Maryland.....	52.07	364.60	87.86	603.62	.73	4.63	.12	.485
Mississippi.....	43.29	86.51	36.13	85.42	1.08	2.20	.77	.962
North Carolina.....	27.30	102.75	27.87	107.00	.71	2.36	.39	.697
Oklahoma.....	17.79	19.57	11.16	30.45	1.94	1.274	.87	.1769
South Carolina.....	17.82	24.26	24.45	33.59	.55	.67	.38	.351
Tennessee.....	33.10	51.48	35.90	56.86	.80	1.08	.39	.378
Texas.....	34.08	76.92	15.77	37.80	1.35	2.54	.40	.391
Virginia.....	13.27	60.39	17.08	80.08	.37	1.56	.14	.372
West Virginia.....	34.12	77.55	37.18	103.39	.93	2.03	.35	.212
Weighted averages.....	31.51	64.47	24.58	59.79	.89	1.81	.36	.41

¹ Based on the 1900 United States Census.² Based on the 1910 United States Census.³ Based on the 1902 United States Census.⁴ Based on the 1912 United States Census.

COUNTY AND DISTRICT ROAD AND BRIDGE BOND ISSUES.

The total county and district road and bridge bonds outstanding on January 1, 1915, in the Southern States amounted to \$64,639,060.83. In the year 1914 there was expended from local bond issues \$13,206,275.71; there was retired, \$1,017,164.34; there was voted \$14,165,201.60, and there was sold \$12,738,016.60. In addition to the county and district bonds the State of Maryland had outstanding on January 1, 1915, \$12,410,000 of road and bridge bonds. These bonds were issued for the purpose of building a system of State roads. This makes a total of road and bridge bonds outstanding on January 1, 1915, State and local, of \$77,049,060.83.

Information in regard to bond issues by States is presented in Table 3, and detailed information, showing bond issues by counties, is shown in the State chapters.

TABLE 3.—*County and district road and bridge bond issues.*

States.	Total out- standing Jan. 1, 1915.	Expended from bond issues during 1914.	Retired during 1914.	Voted during 1914.	Sold during 1914.
Alabama.....	\$5,418,000.00	\$1,013,210.00			
Arkansas.....	1,467,066.00			\$1,191,426.00	\$1,191,426.00
Delaware.....	1,280,000.00	362,000.00		150,000.00	150,000.00
Florida.....	5,959,199.22	765,051.77	\$18,500.00	800,000.00	1,505,000.00
Georgia.....	127,500.00		2,050.00	60,000.00	
Kentucky.....	705,000.00	19,000.00		150,000.00	125,000.00
Louisiana.....	1,588,835.26	486,388.69	24,500.00	1,732,000.00	1,161,000.00
Maryland.....	443,700.00	114,542.36	26,500.00	26,000.00	26,000.00
Mississippi.....	8,327,172.00	2,051,452.71	40,000.00	1,225,500.00	1,778,500.00
North Carolina.....	8,955,300.00	2,430,000.00		1,119,500.00	2,709,000.00
Oklahoma.....	1,440,000.00				
South Carolina.....	460,000.00	34,000.00		75,000.00	75,000.00
Tennessee.....	6,898,276.89	778,306.52	128,421.11	486,500.00	445,000.00
Texas.....	14,615,016.53	4,152,456.72	266,255.00	6,783,275.60	3,119,990.60
Virginia.....	5,650,994.93	999,866.94	510,938.23	366,000.00	452,100.00
West Virginia.....	¹ 1,303,000.00	(²)	(²)	(²)	(²)
Total.....	64,639,060.83	13,206,275.71	1,017,164.34	14,165,201.60	12,738,016.60

¹ July 1, 1915.² Unable to ascertain amounts.

ROAD MILEAGE.

The total road mileage in the Southern States as of January 1, 1915, was 814,565, of which 73,594.78 miles, or 9.03 per cent, were surfaced. This does not include streets in incorporated cities and towns. By comparing these figures with former investigations in the same States it appears that between December 31, 1909, and December 31, 1914, 30,018.60 miles were surfaced. The total road mileage and the mileage surfaced as of 1914, and comparative mileage for 1909, are shown for the Southern States in Table 4. Detailed information on this subject is presented by counties in the State chapters.

TABLE 4.—*Road mileage.*

States.	Total road mileage close of 1914.	Miles surfaced close of 1914.	Miles surfaced 1910 to 1914, inclusive.	Percentage surfaced.	
				1909	1914
Alabama.....	55,446	4,988.5	1,724.57	6.58	8.99
Arkansas.....	50,743	1,097.5	11.75	2.97	2.16
Delaware.....	3,674	243.5	57.10	6.22	6.62
Florida.....	17,995	2,830.47	1,078.12	9.97	15.72
Georgia.....	80,669	12,342.12	6,864.12	7.27	15.30
Kentucky.....	57,916	12,403.28	2,288.33	18.82	21.40
Louisiana.....	24,563	2,067.62	1,796.12	1.32	8.42
Maryland.....	16,458	2,489.26	346.96	12.77	15.15
Mississippi.....	45,779	2,133.35	1,791.10	.86	4.66
North Carolina.....	50,758	6,003.75	3,690.75	4.79	11.82
Oklahoma.....	107,916	121.6	¹ 239.40	.50	.11
South Carolina.....	42,226	3,270.5	¹ 264.25	11.02	7.74
Tennessee.....	46,050	8,102.0	2,748.50	11.66	17.59
Texas.....	128,960	10,526.79	5,640.79	3.80	8.16
Virginia.....	53,388	3,909.57	2,006.82	4.38	7.32
West Virginia.....	32,024	1,064.97	473.57	1.84	3.32
Total and average.....	814,565	73,594.78	30,018.60	6.08	9.03

¹ Decrease.

The relation of total mileage and surfaced mileage to area and rural population in the Southern States for the years 1904, 1909, and 1914 is presented in Table 5.

TABLE 5.—*Relation of total mileage and surfaced mileage to area and rural population.*

States.	Total mileage.						Surfaced mileage.					
	Per square mile of area.			Per 1,000 rural population.			Per square mile of area.			Per 1,000 rural population.		
	1904	1909	1914	1904 ¹	1909 ²	1914 ²	1904	1909	1914	1904 ¹	1909 ²	1914
Alabama.....	0.97	0.96	1.08	31.5	28.0	31.3	0.033	0.063	0.097	1.06	1.84	2.82
Arkansas.....	.67	.69	.96	30.3	26.5	36.9	.004	.02	.02	.196	.79	.80
Delaware.....	1.53	1.53	1.86	30.3	28.5	34.9	.03	.095	1.24	.667	1.77	2.32
Florida.....	.31	.32	.33	41.2	32.9	33.6	.016	.032	.052	2.09	3.28	5.29
Georgia.....	.96	1.40	1.37	30.5	39.7	38.9	.028	.101	.210	.873	2.88	5.96
Kentucky.....	1.42	1.33	1.44	34.0	30.9	33.4	.236	.251	.308	5.64	5.83	7.15
Louisiana.....	.54	.55	.54	24.5	21.5	21.1	.0007	.007	.05	.0334	.0284	1.78
Maryland.....	1.63	1.68	1.65	28.1	26.3	25.8	.15	.22	.25	2.63	3.36	3.90
Mississippi.....	.83	.85	.99	27.0	24.9	28.8	.003	.007	.046	.104	.215	1.34
North Carolina.....	1.00	.99	1.04	29.1	25.5	26.8	.025	.047	.123	.087	1.22	3.18
Oklahoma.....	1.10	1.02	1.55	59.5	53.3	80.7	.000	.0052	.0017	.000	.27	.0912
South Carolina.....	1.30	1.05	1.38	35.7	24.8	32.7	.061	.115	.107	1.60	2.74	2.53
Tennessee.....	1.17	1.10	1.10	28.9	26.3	26.4	.102	.128	.194	2.52	3.07	4.64
Texas.....	.46	.49	.49	48.0	43.6	43.6	.081	.186	.401	.841	1.65	3.56
Virginia.....	1.29	1.07	1.32	34.2	27.3	33.7	.039	.047	.097	1.05	1.20	2.46
West Virginia.....	1.06	1.33	1.33	31.4	32.3	32.3	.001	.002	.044	.31	.595	1.07
Average.....	.78	.83	.92	34.0	31.9	35.7	.031	.050	.083	1.35	1.93	3.23

¹ Based on the United States census for 1900.² Based on the United States census for 1910.

A diagram, Fig. 1, shows the percentage of surfaced roads for the Southern States at the close of the years 1904, 1909, and 1914.

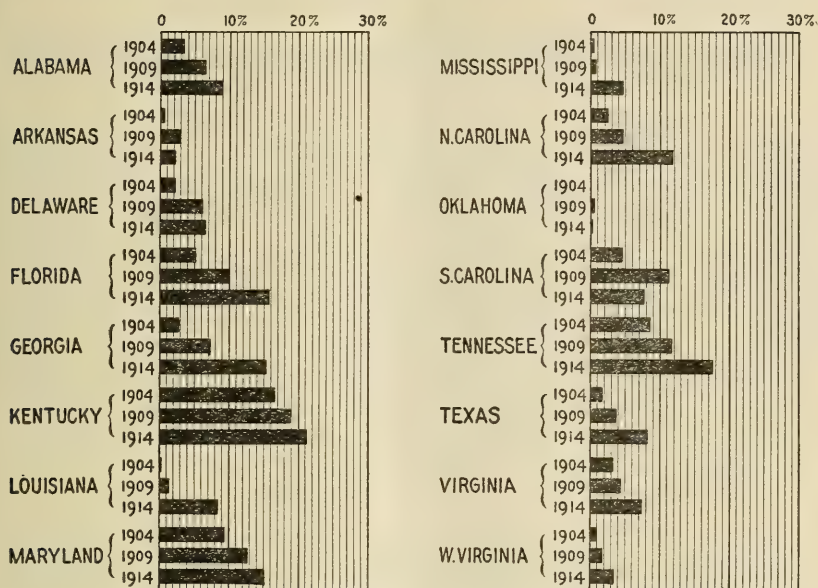


FIG. 1.—Percentage of surfaced roads in Southern States 1904, 1909, and 1914.

This diagram also shows in a striking manner the strides which have been made in road improvement in the South during the past 10 years.

TYPES OF SURFACED ROADS.

Of the 73,594.78 miles of surfaced roads in the Southern States at the close of 1914, 29,287.88 miles, or 39.80 per cent, were sand clay; 21,377.37 miles, or 29.05 per cent, were macadam; 17,440.02 miles, or 23.7 per cent, were gravel; 1,994.36 miles, or 2.71 per cent, were bituminous macadam; 1,924.68 miles, or 2.61 per cent, were shell; 379.81 miles, or 0.51 per cent, were brick; 273.24 miles, or 0.37 per cent, were concrete; and 917.42 miles, or 1.25 per cent, were surfaced with other materials. The distribution of types of surfaced roads as of January 1, 1915, is shown by States in Table 6.

TABLE 6.—*Distribution of types of surfaced roads, 1914.*

States.	Types.							Total.
	Macadam.	Bituminous macadam.	Gravel.	Sand clay.	Shell.	Brick.	Concrete.	
Alabama.....	431.00	31.00	2,589.50	1,916.00	20.00	-----	1.00	4,988.50
Arkansas.....	362.50	4.00	535.00	175.00	-----	-----	21.00	1,097.50
Delaware.....	161.50	35.50	21.00	-----	25.50	-----	-----	243.50
Florida.....	829.16	42.80	42.50	1,163.00	362.77	256.24	12.00	2,830.47
Georgia.....	234.00	87.00	1,073.00	10,778.00 ¹	45.00	-----	.40	12,342.12
Kentucky.....	10,628.00	59.03	1,713.50	-----	-----	.25	2.50	12,403.28
Louisiana.....	-----	-----	430.00	1,448.00	107.50	-----	-----	2,067.62
Maryland.....	488.70	1,042.31	243.95	69.00	455.96	-----	189.34	2,489.26
Mississippi.....	86.00	29.50	1,281.10	604.25	114.00	-----	14.00	2,133.35
North Carolina.....	1,111.00	9.00	529.00	4,313.50	-----	-----	1.25	6,003.75
Oklahoma.....	6.70	3.00	6.90	105.00	-----	-----	-----	121.60
South Carolina.....	27.50	3.50	85.00	3,101.00	53.50	-----	-----	3,270.50
Tennessee.....	4,550.50	148.00	2,788.00	613.00	-----	.50	2.00	8,102.00
Texas.....	511.00	181.00	5,258.98	3,490.48	740.45	-----	11.25	10,526.79
Virginia.....	1,177.89	255.77	822.09	1,511.65	-----	-----	-----	3,909.57
West Virginia.....	771.92	62.95	20.50	-----	-----	121.10	18.50	1,064.97
Total.....	21,377.37	1,994.36	17,440.02	29,287.88	1,924.68	379.81	273.24	73,594.78
Per cent of total surfaced.....	29.05	2.71	23.70	39.80	2.61	.51	.37	100.00

¹ Principally sand asphalt.² Principally shell.³ Shale.

Detailed information regarding sources and amounts of revenues, bonds issued and outstanding, total mileage of roads, mileage surfaced, systems of administration, and other factors affecting road improvement is presented in the following chapters for the Southern States.

ALABAMA.

Alabama has a land area of 51,279 square miles, a total road mileage of 55,446, and a population, according to the 1910 Census, of 2,138,093. The State has a population of 41.7 per square mile of area and 38.56 per mile of road, with 1.08 miles of road per square mile of area. Of the population in 1910, 82.7 per cent, or 1,767,662, was rural, thus indicating a rural population of 31.9 per mile of road.

In 1911 the legislature enacted a law creating a State highway department, which is composed of a State highway commission and a State highway engineer. The State highway commission consists of a professor of civil engineering from the Alabama Polytechnic Institute, the State geologist, and three other members appointed by the governor.

The State highway engineer is elected by the State highway commission and holds office subject to the pleasure of the commission. The State highway engineer, with the consent and advice of the State highway commission, may employ such assistant engineers and clerical help as may be necessary. He is vested with authority to determine the character and have general supervision of the construction and repair of all State-aid roads, and may be consulted by

local road authorities concerning any question that involves highways and bridges under their control. He may in like manner call on such local authorities for any information or assistance they may be able to render with reference to the highways under their control.

The act creating the State highway department required the State highway engineer to prepare a map of such of the main highways of the State as in his judgment were of sufficient importance to be designated as a system of trunk or State roads, to be improved by the State and counties jointly, and to report same to the State highway commission for submission to the legislature. Such report was submitted to the legislature and, by an act approved September 10, 1915, a system of State trunk roads was designated for improvement and maintenance in accordance with standards established by the State highway department. It was made unlawful to spend any money appropriated by the State on any other roads than those comprised in said designated system until after their improvement. The State will pay one-half the cost of constructing the trunk line roads. An annual appropriation of \$154,000 is made from the net revenue derived from the convict fund for the support of the State highway department and for State aid in road work.

It is the duty of the State highway commission to prescribe rules and regulations under which the State highway engineer shall require roads constructed or improved in any county with State aid to be kept in proper repair, and should any county fail or refuse to carry out any reasonable recommendations of the State highway engineer relating to the repair of such roads, the work may be done by the State and the expense therefor shall be paid by the county or may be paid out of any money that may be due or that may become due such county from the State-aid appropriation.

The courts of county commissioners, boards of revenue, or other like governing bodies in the several counties, are vested with the general supervision of the public roads, bridges, and ferries in their respective counties. They may establish, promulgate, and enforce rules and regulations and make and enter into such contracts as they may deem necessary for the construction and maintenance of a good system of public roads, bridges and ferries, and regulate the use thereof.

All able-bodied males between 18 and 45 years of age are liable to work on the roads in their respective counties not more than 10 days each year or to pay such amount in lieu thereof, not exceeding \$5, as may be determined by the court of county commissioners, board of revenue, or other like governing body. The amount of money paid in lieu of said road work shall go into the county road fund. No person shall be liable to road duty in any county having an assessed property valuation of \$100,000,000.

The courts of county commissioners, boards of revenue, or other like governing bodies, may, for the purpose of maintaining roads, bridges or ferries, impose upon the owners of vehicles used upon the public roads of the county such license taxes as they may deem advisable. On vote of a majority of the qualified electors of a county voting at an election held for that purpose, bonds may be issued for public improvements or to pay debts created for such improvements, including the building of roads and bridges, but the aggregate amount of indebtedness that may thus be created shall not exceed 3 per cent of the assessed value of the property in such county. Said courts, or boards, may levy and collect such special taxes as they may deem necessary, not to exceed one-fourth of 1 per cent of the assessed value of property in the county, for the purpose of paying any debt or liability created, or that may be created, for erecting public buildings or constructing roads and bridges.

Convicts of a county may be worked on its roads, bridges or ferries, or in the preparation of road materials, or said convicts may be hired to or from another county or from the State.

REVENUES APPLIED TO ROADS AND BRIDGES IN 1914.

It was impossible to secure complete information on taxation and revenues from every county in the State, but from the reports received it appears that \$2,488,805.51 was received from taxation and applied to roads in 1914. Of this amount \$612,095.02 was obtained from the regular levy, \$103,822 from statute labor tax paid in cash, \$91,237.59 from general funds and applied to interest and principal on road bonds, and \$1,681,650.90 from general and special funds.

Fifteen out of the 67 counties in the State report that they are still making use of the statute labor tax. A total of 47,600 men is reported as having worked the roads from $3\frac{1}{2}$ to 10 days each. The cash value of this labor at the prevailing rate of wages amounted to \$302,025.

By adding \$302,025, the cash value of the labor tax, and \$1,013,210, the amount obtained from bond issues and expended on roads in 1914, and \$144,978, the State-aid appropriation for 1914, to the totals above, it appears that the aggregate expenditure for roads in 1914 amounted to \$3,949,019. This includes \$91,237.59 paid out by counties for interest and principal on road bonds. It was impracticable to separate this item from the total. In 1904 the total property and labor tax amounted to \$1,576,434.27, thus showing that during the past 10 years the road revenues increased \$2,372,584.73, or 150.5 per cent.

The use of the statute labor tax appears to have declined steadily since 1904, for during that year 153,419 men were reported as having

worked the roads, and the value of such labor amounted to \$1,198,394. The principal increases in revenues are, therefore, property taxes paid in cash, which accounts for the steady increase in the surfaced road mileage of the State.

The county tax rates for roads, the total receipts from taxation and the statute labor road tax are shown by counties in Table 7.¹

ROAD AND BRIDGE BONDS.

On January 1, 1915, a total of \$5,418,000 of county road and bridge bonds was outstanding. This includes \$372,000 of road warrants. During the year 1914, \$1,013,210 was expended from road bonds. The total bonds and warrants outstanding and the amounts expended from bond issues in 1914 are shown by counties in Table No. 23.

ROAD MILEAGE.

In 1904 Alabama reported 50,089 miles of public roads, in 1909, 49,639 miles, and in 1914, 55,446 miles. The surfaced roads of the State reported were 1,720 miles for 1904, 3,263.93 miles in 1909, and 4,988.5 miles in 1914. The percentage of all roads surfaced was therefore 3.43 per cent in 1904, 6.58 per cent in 1909, and 8.99 per cent in 1914. Of the latter 431 miles were macadam, 2,589.5 gravel, 1,916 sand clay, 31 bituminous macadam, 20 shell, and 1 concrete. In addition to the surfaced roads, 2,023.5 miles were reported as graded and drained earth roads. While some of the counties reported a smaller mileage of surfaced roads in 1914 than in 1909, it appears that if the State is taken as a whole a total of 1,724.57 miles of roads were surfaced during the five-year period, January 1, 1910, to December 31, 1914.

The total mileage of roads, the miles surfaced, the percentage surfaced, and the mileage of graded and drained earth roads are shown by counties in Table 37.

ARKANSAS.

Arkansas has a land area of 52,525 square miles, a total road mileage of 50,743, and a population, according to the 1910 census, of 1,574,449. The State, therefore, has a population of 29.97 per square mile of area and 31.02 per mile of road, with 0.96 mile of road per square mile of area. Of the population in 1910, 87.1 per cent, or 1,371,768, was rural, thus indicating a rural population of 27.03 per mile of road.

In the legislative session of 1913 there was established the department of State lands, highways and improvements, the executive head of which is the Commissioner of State lands, highways and improvements. There also was created a State highway commission

¹ All tables referred to in the text under the respective States will be found in the appendix.

to consist, ex officio, of the commissioner of State lands, highways and improvements, as chairman, and two other members to be appointed by the governor to serve for terms of two years each. Subject to the approval of the State highway commission, the commissioner of State lands, highways and improvements appoints a State highway engineer. The head professor of civil engineering in the State university is ex officio consulting engineer of the department of State lands, highways and improvements. There is a highway improvement fund which consists of all fees accruing in the office of State lands, highways and improvements, and the proceeds from the registration and licensing of motor vehicles. The work of the State highway department embraces the educational, advisory, and constructive phases of road work as follows:

(1) The holding of road institutes in each county every year and the issuance of bulletins pertaining to road work.

(2) Consultation relative to and investigation of all road and bridge matters upon request.

(3) Making preliminary surveys, plans, estimates, and specifications of all road work contemplated under the general road district law and the working of all available State convicts on the public roads or in the preparation of road materials.

The constitution gives the county courts exclusive original jurisdiction over all matters relating to roads, bridges and ferries. The county courts, with approval of the quorum court, may appoint a commissioner of roads, highways and bridges for their respective counties, to have charge of the building and repairing of roads and bridges under the direction of the county judge. Said court shall divide the county into convenient road districts and appoint an overseer for each such district. In six counties a county highway engineer may be appointed by the county courts for a term of one year. Where a county highway engineer is appointed he shall have supervision over all road work and shall direct the overseers in the performance of their duties. In counties having the county engineer system, all work may be done by contract, the county engineer to prepare plans, estimates and specifications and let the work to the lowest responsible bidder, the funds for paying same to be derived from the general $2\frac{1}{2}$ or 3 mill road tax. An optional system for working roads is provided, subject to adoption by the county court, whereby each political township is made a road district and a township road overseer is to be elected at each general election.

Road improvement districts may be created by the county court when petitioned for by a majority in land value, acreage, or number of land owners within the proposed district and after the required public notice and hearing.

An appeal from the order of the county court creating a road district may be taken at any time within 30 days. The county court at the same time that it orders the creation of a road improvement district shall appoint three owners of real estate in the district to act as the board of commissioners for such district. The board of commissioners may appoint an engineer or have the work done under direct supervision of the State highway department. The cost of the proposed improvement shall be paid by a tax levy on real property in proportion to the benefits that will accrue thereto and the amount of such benefits shall be determined by a board of assessors to be appointed for that purpose, but not more than 20 per cent of such tax may be required to be paid in any one year.

Numerous special laws have been enacted under which road and bridge work in many of the counties is done. These special laws vary the system of administration slightly from that provided by the general law and in many of the counties create road officials under designations or titles different from those authorized by the general law.

The county court, with approval of the quorum court, may levy annually for road purposes not less than $2\frac{1}{2}$ mills nor more than 3 mills on each \$1 of taxable property in the county. Various provisions exist whereby road bonds may be issued and limiting the amount of such bonds that may be issued, the maximum limit being prescribed for road improvement districts which are authorized to issue bonds in such amounts, exclusive of interest, as will not exceed 30 per cent of the total assessed value of the real property located within the district.

Male persons between the ages of 18 and 45, not exempt by law, may be required to work not exceeding 10 days annually on the public highways, or to pay in lieu thereof the sum of \$1 for each day of work so required. However, most counties require only four days. Provision is made for the working of county convicts on the public highways.

REVENUE APPLIED TO ROADS AND BRIDGES DURING 1914.

In 1914 the total receipts from taxation applied to roads and bridges amounted to \$1,522,696.20, of which \$1,259,242.20 was obtained from general county taxes, \$103,454 was the cash value of the statute labor tax, \$45,000 was obtained from bond issues, and \$115,000 appropriated by the State, of which \$25,000 was for engineering and inspection, \$15,000 for administration of the State highway department and \$75,000 for the purchase of a crushing plant to be used by State prisoners.

In 1904 the total expenditures for public roads in Arkansas amounted to \$1,395,342.80, of which \$681,933.80 was obtained from

property taxes paid in cash, while \$713,409 represented the cash value of the statute labor tax. It thus appears that the total receipts from taxation, including the State appropriation, applied to roads increased during the 10-year period \$127,353.40, or 9.1 per cent. The receipts from the property tax alone during this period increased 84.6 per cent, while the receipts from the statute labor tax were nearly seven times as great in 1904 as in 1914. It is quite likely, however, that complete information on the statute labor tax was not obtained for the year 1914.

The information showing the revenue applied to roads and bridges for the year 1914 is contained in Table 8.

ROAD AND BRIDGE BONDS AND SCRIP.

The total road and bridge bonds and scrip outstanding on January 1, 1915, amounted to \$1,467,066, comprising \$1,249,926 in bonds and \$217,140 in scrip. The scrip consisted of noninterest-bearing short-time loans or warrants issued to meet current expenses. During the year 1914 a total of \$1,191,426 road and bridge bonds were voted and sold. These bonds run from 12 to 20 years and bear 6 per cent interest. They were sold at from 98 to 101 cents on the dollar.

Detailed information showing bonds and scrip by counties is contained in Table 24.

ROAD MILEAGE.

At the close of 1914, Arkansas reported 50,743 miles of public road, of which 1,097 miles, or 2.16 per cent, were surfaced. Of the surfaced roads 362.5 miles were plain macadam, 535 miles gravel, 175 sand clay, 21 concrete, and 4 miles bituminous macadam. There were also 16,305 miles of earth road reported as graded and drained. Pulaski County reported 198.5 miles, or 39 per cent, of surfaced roads. This is the only county in the State that reported more than 100 miles of surfaced road. There are 39 counties in the State which reported no surfaced roads. Quite a number of counties reported a smaller mileage of surfaced roads than was reported for 1909. Several counties also reported large increases in total road mileage, with the result that the total mileage of all roads reported increased from 36,445 miles in 1909 to 50,743 miles in 1914, and that the percentage of surfaced roads shows a decrease on this account from 2.97 in 1909 to 2.16 in 1914. In other words, if the figures reported are correct, Arkansas only had 11.75 more miles of improved roads in 1914 than in 1909. Mileage of surfaced roads outside of incorporated cities is shown in Table 38.

DELAWARE.

Delaware has an area of 1,965 square miles. It has only three counties, of which Sussex is the largest, having an area of 913 square miles, and New Castle is the smallest, having an area of 435 square miles. In 1910 the State had a total population of 202,322, of which 87,411 were in the city of Wilmington.

Each county in Delaware conducts its highway work as a distinct unit. In New Castle County there is a State highway commissioner appointed by the governor for the one county, and a county road engineer appointed by the levy court, but the same man may hold both offices. In the other counties the levy court is the governing body, and a county engineer is appointed by the court. The legislature each year appropriates \$30,000 for highway purposes, each county receiving \$10,000 as its share.

REVENUES APPLIED TO ROADS AND BRIDGES.

In 1914 a total of \$511,628 was applied to road and bridge work in Delaware. Of this amount, \$118,628 was derived from county taxation, \$31,000 from State-aid appropriations and \$362,000 from bond issues. In 1904 the total revenues applied to roads and bridges amounted to \$90,803, thus showing that during the 10-year period, 1904 to 1914, the expenditures increased \$420,825, or 463 per cent. Table 9 shows the rates of taxation, the amounts derived from taxation and the amounts received from the State and applied to roads in 1914.

ROAD AND BRIDGE BONDS.

On January 1, 1915, the total road and bridge bonds outstanding amounted to \$1,280,000 for Kent and New Castle Counties only. In 1914 New Castle voted and sold \$150,000 of bridge bonds. During 1914, \$362,000 were expended by the counties from road and bridge bonds issued that year and previously. The total bonds outstanding on January 1, 1915, the bonds issued in 1914, and the expenditures from bond funds in 1914 are shown by counties in Table 25.

ROAD MILEAGE.

At the close of 1914 Delaware had 3,674 miles of public road, of which 243.5 miles, or 6.62 per cent, were surfaced. Of the surfaced roads 161.5 miles were macadam, 35.5 bituminous macadam, 21 gravel, and 25.5 shell. In addition to the surfaced roads, 270 miles were graded and drained earth roads. The mileage figures for Delaware are shown in Table 39.

Comparing the mileage figures of 1914 with similar data collected for 1909 shows that the mileage of surfaced roads increased 57.1 miles in the five-year period. The percentage of roads surfaced in 1909 was 6.22.

FLORIDA.

By J. P. CLARKSON, *Collaborator United States Office of Public Roads and Rural Engineering.*

Florida has a land area of 54,861 square miles, a total road mileage of 17,995, and a population, according to the 1910 Census, of 752,619. The State, therefore, has a population of 13.71 per square mile of area and 41.82 per mile of road, with 0.33 mile of road per square mile of area. Of the population in 1910, 70.9 per cent, or 533,539, was rural, a rural population of 29.65 per mile of road.

A State road department to consist of five persons, one from each congressional district, appointed by the governor, subject to confirmation by the State senate, was created in 1915. The members of the department elect annually from their membership a chairman and a secretary. The department is required to employ some person well versed in road building to be State road commissioner, and may employ also necessary clerical and engineering assistants. Fifteen per cent of all county motor vehicle licenses is paid into the State treasury for the maintenance of the State road department. The work of the department is mostly of an advisory nature.

General jurisdiction over roads and bridges in the several counties vests in the boards of county commissioners, composed of one commissioner elected from each of the five districts into which each county is divided. Each county commissioner's district constitutes a road district, and it is the duty of the county board of commissioners at its January meeting each year to appoint three commissioners for roads and bridges in each district. The road commissioners lay off the roads in their respective districts into subdivisions of convenient length and appoint an overseer for each subdivision. Each board of commissioners is authorized to employ a county engineer, who, subject to the orders of said board, has general supervision and control of all road and bridge work of the county. On petition of 25 per cent of the duly registered voters who are freeholders residing within territory which it is desired to have constituted a "special road and bridge district," the board of county commissioners shall call an election to determine whether such district shall be created and whether funds for improving the roads therein shall be raised by a special tax or by a bond issue. All work in "special road and bridge districts" is under the supervision and control of the board of county commissioners. Special tax road districts are created by a majority vote at an election called for that purpose on petition of one-fourth of the qualified electors who pay taxes on real and personal property and reside in the district. In addition, a number of special road laws have been enacted and are in force in many counties.

Boards of county commissioners are authorized to levy a general road tax of not to exceed 8 mills on each \$1 of real and personal prop-

erty in their respective counties. Said boards also may levy a special road and bridge tax of not to exceed 5 mills on the \$1 of all real and personal property in the county, one-half of the amount derived therefrom in incorporated cities to be turned over to the municipal authorities thereof for use on roads and streets. There may be levied in "special tax road districts" not to exceed 5 mills on the \$1. The boards of county commissioners are authorized to levy annually on all taxable property in "special road and bridge districts" a tax of not exceeding 10 mills on the \$1 for the repair and maintenance of the roads and bridges therein and not exceeding 20 mills on the \$1 to pay for the improvements voted at the special election at which such "special road and bridge district" was created. Road bonds may be issued when authorized by a majority vote of the registered voters in the respective counties.

Every able-bodied male person, not exempt by law, over 21 and under 45 years of age, is liable to not more than 6 days' labor on the roads and bridges or to pay \$3 in lieu thereof.

The working of both State and county convicts on the public roads is authorized by law.

REVENUES APPLIED TO ROADS AND BRIDGES IN 1914.

The total revenues applied to roads and bridges in 1914 amounted to \$2,280,255.09 and comprised the following items: Receipts from general county taxes, \$969,825.36; receipts from auto licenses, convicts hired out, special taxes, labor taxes, and other sources, \$545,377.96; and expenditures from bond issues, \$765,051.77.

In 1904 the total expenditures for this purpose amounted to \$577,577.10, showing an increase in the 10-year period of \$1,702,677.99, or 294.7 per cent. The cash value of the statute labor tax amounted to \$140,393 in 1904, but in 1914 this amounted to only \$18,069.09, which shows that the statute labor tax has almost disappeared in Florida.

The receipts from taxation and the tax rates for general county road purposes are shown by counties in Table 10.

ROAD AND BRIDGE BONDS.

The total amount of road and bridge bonds outstanding on January 1, 1915, amounted to \$5,959,199.22. This included \$48,000 of road warrants. The total expenditure from bonds during the year 1914 amounted to \$765,051.77, a total of \$800,000 of bonds was voted, \$1,505,000 sold and \$18,500 retired.

Detailed information regarding the Florida road bonds is given by counties in Table 26.

ROAD MILEAGE.

The total mileage of public roads at the close of the year 1914 amounted to 17,995, of which 2,830.47 miles, or 15.73 per cent, were surfaced. Of the surfaced roads 829.16 miles were plain macadam, 42.80 bituminous macadam, 362.77 shell, 1,163 sand-clay, 256.24 brick, 42.5 gravel, 12 concrete, and 122 other materials, principally sand-asphalt. The State has 3,686 miles of graded and drained earth roads.

In mileage of surfaced roads, Marion County stands first, with 200 miles, or 22.22 per cent; Gadsden County second, with 185 miles, or 46.25 per cent; Palm Beach County third, with 160 miles, or 44.44 per cent; Orange County fourth, with 157 miles, or 48.3 per cent; Lake County fifth, with 150 miles, or 46.15 per cent; and Duval County sixth, with 144 miles, or 56.47 per cent. Six other counties have more than 100 miles surfaced and 10 counties report none.

In 1909 the surfaced roads amounted to 1,752 miles, or 9.97 per cent, of the total, thus showing that during the 5-year period 1,078 miles were surfaced.

The mileage statistics for the various counties are shown in Table 40.

GEORGIA.¹

By S. W. McCallie, *State Geologist*.

Georgia has a land area of 58,725 square miles, a total road mileage of 80,669, and a population, according to the 1910 census, of 2,609,121. The State therefore has a population of 44.42 per square mile of area and 32.34 per mile of road, with 1.37 miles of road per square mile of area. Of the population in 1910, 79.4 per cent, or 2,070,471, was rural, thus indicating a rural population of 25.66 per mile of road.

The surface configurations of Georgia vary from a low, level, almost featureless plain only a few feet above sea level to high rugged mountains attaining an altitude of more than 4,000 feet. The State is naturally divided into five physiographic divisions: The Coastal Plain, the Piedmont Plateau, the Appalachian Mountains, the Appalachian Valley and the Cumberland Plateau.

The board of county commissioners, in counties where such boards have been created, or the commissioners of roads and revenues, or the ordinary of each county, has jurisdiction over the roads therein. These officials, in many cases, appoint three district road commissioners for each road district in the county and the district road commissioners appoint one or more road overseers for their respec-

¹ The information contained in the tables [see Appendix] concerning the public roads of Georgia was collected by the State geological survey, in cooperation with the United States Office of Public Roads and Rural Engineering, largely by correspondence, but in some instances personal visits were necessary. The work was begun about the 1st of March, 1915, and completed in December, 1915.

tive districts, the latter having immediate charge of road work. The commissioners of roads and revenues, the ordinary, or such other officers as have charge of county matters in any county, may appoint a "superintendent of public roads." In counties of more than 15,000 and not more than 85,000 population the commissioners of roads and revenues, upon the recommendation of the grand jury, may employ one or more persons as "inspector of roads and bridges."

The commissioners of roads and revenues are authorized to levy a tax of not more than four-tenths of 1 per cent on all taxable property for a "public road fund." They are also authorized to levy a general road tax of from 1 to 2½ mills on the dollar. In addition to the general road taxes authorized by law many counties operate under special laws and are authorized to make special levies in excess of or in lieu of the general levy. Any county or subdivision thereof may issue road bonds in an amount not exceeding 7 per cent of the assessed value of all taxable property therein, when authorized by a two-third vote of the qualified voters of the county. Bonds may be issued without being submitted to a vote of the people in an amount not exceeding one-fifth of 1 per cent of the assessed value of all taxable property in the county.

All male persons between the ages of 21 and 50 years, not exempt by law, are liable to work not exceeding 10 days each year on the roads or commute for same by paying from \$2 to \$5 in cash, the requirements varying in the different counties. State and county convicts may be worked on the roads.

REVENUES APPLIED TO ROADS AND BRIDGES IN 1914.

The total revenues applied to roads and bridges in 1914 amounted to \$3,688,172.25 and comprised the following items: County road and bridge tax, \$2,827,352; amount obtained from automobile licenses, \$92,739; amount obtained from commutation tax, \$708,285; and cash value of statute labor tax, \$59,796.25.

In 1904 the total revenues applied to roads and bridges amounted to \$2,080,872.33. In the 10-year period revenues for this purpose increased \$1,607,299.92, or 77.2 per cent.

Information in regard to the tax rates and the receipts from taxation of the various counties is shown in Table 11.

ROAD AND BRIDGE BONDS.

According to the reports received, \$127,500 of road and bridge bonds were outstanding on January 1, 1915, as follows: Ben Hill County, \$8,000; Bleckley County, \$8,000; Clarke County, \$76,500; and Hancock County, \$35,000. In 1914 Dade County voted \$60,000 of 5 per cent 20-year road and bridge bonds, which were sold during

1915 at 98½ cents on the dollar. Road bonds were retired as follows: Ben Hill County, \$350; Towns County, \$700 and Turner County, \$1,000.

ROAD MILEAGE.

At the close of the year 1914, according to reports received, Georgia had 80,669 miles of public road, of which 12,342.12, or 15.3 per cent, were surfaced. Of the surfaced roads, 10,778 miles were sand clay, 1,073 miles gravel, 234 miles macadam, 87 miles bituminous macadam, 45 miles shell, 1.7 miles brick, 0.4 mile concrete, and 123 miles not classified as to type.

In mileage of surfaced roads, Emanuel County stands first with 500 miles, or 68.8 per cent; Decatur County, second, with 500 miles, or 67 per cent; Richmond County, third, with 405 miles, or 81 per cent; Bulloch County, fourth, with 400 miles, or 53.4 per cent. There are 6 counties having between 300 and 400 miles surfaced, 14 counties having between 200 and 300, 29 counties having between 100 and 200, and 52 counties that reported no surfaced roads. There are 30,554 miles of roads reported as graded and drained earth.

In 1909 there were 5,978 miles, or 7.27 per cent, reported as surfaced, thus indicating that during the 5-year period 6,364 miles were surfaced. Information showing the total mileage of all roads and the miles surfaced in the various counties is contained in Table 41.

KENTUCKY.

By R. C. TERRELL, *State Commissioner of Public Roads and Collaborator United States Office of Public Roads and Rural Engineering.*

Kentucky has an area of 40,181 square miles, a total road mileage of 57,916, and a population, according to the 1910 census, of 2,289,905. The State, therefore, has a population of 56.9 per square mile of area and 39.5 per mile of road, with 1.44 miles of road per square mile of area. Of the population in 1910, 75.7 per cent, or 1,734,463 was rural, making a rural population of 29.94 per mile of road.

In 1912 the legislature enacted a law creating a department of public roads, the chief officer of which is the commissioner of public roads, who is appointed by the governor for a term of four years and is required to be a graduate of civil engineering from some reputable university or technical school.

The commissioner of public roads had no authority over county roads, other than in an advisory capacity, and the expenditures of the department of public roads were not to exceed \$25,000 annually, to be paid from the State road fund which was composed of the proceeds of the license tax on motor vehicles. In 1914 a new law was enacted enlarging the powers of the State commissioner of public roads and levying a State tax of 5 cents on each \$100 valu-

ation of all property not exempt from taxation, the proceeds to be credited to the State road fund and apportioned among the several counties of the State in proportion to the road taxes collected therein, no county to receive in any one year more than 2 per cent of the amount collected for the State road fund. Under this new law, a system of public State highways was created to consist of roads connecting the county seats of the various counties of the State, which roads are to be the first to receive State aid.

The commissioner of public roads has general supervision over all public roads and bridges being constructed, improved or maintained in whole or in part by the aid of State money, and he prescribes rules and regulations fixing the duties of county road engineers and their employees in respect to the roads and bridges composing the system of public State highways and determines the method of construction. One-half of the cost of State-aid road work is to be paid by the State and the counties, respectively. The fiscal court has the plans, specifications, and estimates prepared and submits them to the commissioner of public roads for his approval. After such approval the fiscal court may let the work to contract, after due advertisement, the contract to be approved by the commissioner. After the contract is awarded, the commissioner of public roads appoints an inspector to inspect the work required to be done thereunder. The salary of the inspector is paid out of the sum apportioned to the county from the State road fund.

The fiscal or county courts are vested with the general charge and supervision of the public roads and bridges in their respective counties. The county judge, by and with the consent and approval of the fiscal court, is authorized to appoint a county road engineer who shall be either a reputable civil engineer or have had two years practical experience as a road builder and shall have passed a creditable examination by the State commissioner of public roads. The judge of each county court may divide the county into road precincts and appoint an overseer for each precinct.

The taxes for ordinary road and bridge purposes are imposed by the fiscal courts of the counties under a constitutional limit of 50 cents on the \$100 for all purposes other than schools. All able-bodied male citizens over 18 and under 50 years of age, not exempt by law, may be required to work on the public roads, either in person or by able-bodied substitute, not exceeding six days each year. An annual poll tax of \$1.50 may be levied and the proceeds applied to the maintenance of the public roads of the respective counties. Bonds may be issued for road and bridge purposes by the fiscal court when so authorized by a majority vote at an election called for that purpose by the county court upon petition of 150 legal voters who are freeholders of the county. The amount of such

bonds that may be issued shall not exceed 5 per cent of the value of the taxable property therein or shall not require a tax levy for interest and sinking fund in excess of 20 cents on the \$100 of assessed valuation of the county. County prisoners may be worked on the public highways and bridges.

REVENUES APPLIED TO ROADS AND BRIDGES IN 1914.

The total revenue applied to roads during 1914 amounted to \$2,474,621, of which \$2,180,997 was derived from property taxes, \$201,027 representing the cash value of the statute labor tax, \$55,597 poll taxes and donations, \$19,000 expenditures from bond issues, and \$18,000 expended from automobile licenses for the maintenance of the State highway department. A property tax, paid in cash, was levied in 101 of the 120 counties. The rate varied from a minimum of 5 cents to a maximum of 40 cents, and averaged for the State 23.1 cents on the \$100. In 1904 the total revenue applied to roads, including cash value of statute labor taxes, amounted to \$2,148,689.03 thus showing that during the 10-year period expenditures increased \$325,931.97, or 15.1 per cent. The use of the statute labor tax has declined steadily during the past 10 years. In 1904 there were 93 counties in which the statute labor tax was in use and the cash value of the labor performed amounted to over \$1,000,000, but in 1914 there were only 29 counties using this form of taxation and the cash value of the labor performed amounted to only \$201,027.

Information regarding taxation and revenues as applied to roads is shown by counties in Table 12.

ROAD AND BRIDGE BONDS.

The total bonds outstanding on January 1, 1915, according to the reports received, amounted to \$705,000. Lewis County voted \$150,000, in 1914, of which \$125,000 was sold and \$19,000 expended. The Lewis County bonds run for 30 years and bear 5 per cent interest. The bonds outstanding on January 1, 1915, are shown by counties in Table 27.

ROAD MILEAGE.

At the close of the year 1914 Kentucky had 57,916 miles of public road, of which 12,403.28 miles, or 21.4 per cent, were reported as surfaced. Of the surfaced roads, 10,628 miles were macadam, 59.03 bituminous macadam, 1,713.5 gravel, 2.5 concrete, and 0.25 brick.

In surfaced road mileage, Jefferson County stood first, with 779.75 miles, or 85.89 per cent; Grant County second, with 490 miles, or 90.74 per cent; Shelby County third, with 402 miles, or 57.26 per cent; Owen County fourth, with 400 miles, or 66.66 per cent; Warren County also has 400 miles, or 40 per cent, surfaced. Ten counties reported between 300 and 400 miles surfaced; 16 coun-

ties reported between 200 and 300 miles; 14 counties reported from 100 to 200 miles; while 40 counties reported no surfaced roads. Twenty-six counties reported a smaller mileage of surfaced roads for 1914 than was reported by them in 1909. In spite of this decrease, however, the complete returns show that during the 5-year period 1909-1914, 2,288.33 miles of road were surfaced and that the percentage of surfaced roads increased from 18.82 in 1909 to 21.4 in 1914. Mileage statistics for the various counties for the year 1914 are shown in Table 42.

LOUISIANA.

Louisiana has a land area of 45,409 square miles, a total road mileage of 24,563, and a population, according to the 1910 census, of 1,656,388. The State, therefore, has a population of 36.47 per square mile of area and 67.43 per mile of road, with 0.54 mile of road per square mile of area. Of the population in 1910, 70 per cent, or 1,159,872 was rural, thus indicating a rural population of 47.22 per mile of road.

The State board of engineers is required to appoint a State highway engineer and such assistant engineers and other help as may be necessary to the proper conduct of the work of establishing, constructing, maintaining and repairing public highways with bridges, culverts, drains, and other appurtenances and accessories incident thereto. When requested so to do by the police jury of a parish or the municipal authorities of any city, town or village, the State board of engineers is required to furnish such parish, city, town or village with plans and specifications and with such advice and assistance as will tend to create a uniform system of public roads throughout the State.

The State highway engineer, subject to the approval of the State board of engineers, is given authority to determine the character, select the materials and have general supervision of the construction and repair of all highways in the improvement of which State aid may be given. Written application for State aid must be made to the State highway engineer by the police juries of parishes and by the mayors or other governing authorities of cities, towns or villages. Upon receipt of such application the State highway engineer is required to send to such authorities blank forms eliciting such information as he may desire concerning the proposed improvement, and he may, subject to the approval of the State board of engineers, approve the same and have plans, specifications and estimates of cost therefor prepared.

Where the cost of the improvement will exceed \$2,000, it shall be done by contract, but where such cost will be less than \$2,000 it shall be discretionary with the State highway engineer, subject to the approval of the State board of engineers, to let the work to contract

or to have it done by free labor. Of the total cost of all State-aid road work, the State pays one-half, if the funds available are sufficient, and the parish, city, town or village wherein such work of improvement is located is required to pay the remaining portion. The State highway engineer is required to maintain all roads improved with the aid of the State, and the cost of such maintenance is borne one-half by the State and one-half by the parish, city, town or village in which such road may be located. A State highway fund is created to consist of the State road tax levy of one-fourth mill on each \$1 of the assessed value of all property assessed for State taxation.

Jurisdiction over all road matters in the various parishes of the State is vested in the police juries, which are authorized to pass all such ordinances as they may deem necessary relative to roads, bridges and ditches, and to impose fines and penalties for failure to observe their orders. They are required to divide parishes into as many districts as they may think proper for the appointment of overseers of roads and shall appoint one overseer for each such district.

The police juries are authorized to have the work of opening and repairing roads and building and repairing bridges done by contract. They may, and on petition of not less than 25 per cent of the property owners, resident and nonresident, shall divide their parishes into one or more road districts. When petitioned by 50 per cent of the land owners, resident and nonresident, they may divide road districts into subroad districts. On request of 50 per cent or more of the property owners, resident and nonresident, in a road district, the police jury is required to appoint for such district a supervising board of five property owners, to have charge and supervision over the road improvement work to be undertaken therein. Otherwise, the police jury is the board of administration or the governing body for the road districts and subroad districts in their respective parishes. Whenever any road construction exceeds \$2,000, the plans and specifications shall be prepared and submitted for approval to the State board of engineers.

Of the tax levy of 10 mills on the \$1 authorized by the constitution for all county purposes, the police juries may set aside at least 1 mill per annum for the purpose of constructing, maintaining, and repairing the public roads and bridges of their respective parishes. For a like purpose they may impose a per capita tax of \$1 upon each able-bodied male between 18 and 55 years of age, and may levy an annual graduated license tax of not less than 25 cents nor more than \$1 upon each vehicle, including bicycles, kept within the parish or municipality thereof and used on the public roads.

Parishes and road districts, through the police juries, may issue road bonds not to exceed in the aggregate 10 per cent of the assessed property valuation of the parish or road district, when authorized by

a majority vote of the qualified electors voting at an election held for that purpose provided that the annual tax required to meet the bond issue, added to all other special taxes imposed to extinguish bonds issued for similar purposes, shall not exceed 10 mills on the \$1. A special tax for road purposes may be voted in similar manner, if such special tax added to the taxes otherwise levied will not exceed the constitutional limit of 10 mills.

All male persons between 18 and 50 years of age, not exempt by law, may be required to work on the public roads not exceeding 12 days each year or to pay in lieu thereof \$1 for each day. Provision also is made for the working of both State and parish convicts on the public roads.

REVENUES APPLIED TO ROADS AND BRIDGES.

The total revenues applied to roads in 1914 amounted to \$1,777,572.12, as follows: general road tax, \$533,294.10; capitation, vehicle, and special taxes, \$250,648.60; cash value of statute labor tax, \$45,735; expended by State on State highways, \$461,505.73; and expenditures from bond issues, \$486,388.69.

The total expenditures in 1904 amounted to \$951,872.86, thus showing that during the 10-year period expenditures increased \$825,699.26, or 86.7 per cent. The cash value of the statute labor tax decreased from \$606,421 in 1904 to \$45,735 in 1914.

Information regarding taxation and revenues for 1914 is shown by parishes in Table 13.

ROAD AND BRIDGE BONDS.

On January 1, 1915, according to the reports received from the various parishes, the total road and bridge bonds outstanding amounted to \$1,588,835.26. During the year 1914 there was expended from bond issues \$486,388.69; there was voted \$1,732,000; there was retired \$24,500, and there was sold \$1,161,000 of road and bridge bonds. Detailed information in regard to bond issues in the various parishes is presented in Table 28.

ROAD MILEAGE.

At the close of the year 1914, Louisiana had 24,563 miles of public road, of which 2,067.6 miles, or 8.42 per cent, were surfaced. Of the surfaced roads 430 miles were gravel, 1,448 sand clay, 107.5 shell, and 82.1 miles of other materials. There were also 7,453 miles of graded and drained earth roads.

In mileage of surfaced road, Rapides Parish stood first with 709 miles, or 54.16 per cent; Ouachita, second with 308 miles, or 50.65 per cent; Washington, third with 183 miles, or 33.27 per cent; Bossier, fourth with 170 miles, or 40.86 per cent; and De Soto fifth with 100 miles, or 25 per cent. There were 38 parishes which reported no surfaced roads. During the five-year period, from the

close of 1909 to the close of 1914, 1,796.1 miles were surfaced. The per cent of surfaced roads increased, therefore, from 1.32 in 1909 to 8.42 in 1914. Detailed information in regard to Louisiana road mileage is shown in Table 43.

MARYLAND.

By H. C. McAvoy, *United States Collaborator.*

Maryland has a land area of 9,941 square miles, a total road mileage of 16,458, and a population, according to the 1910 census, of 1,295,346. The State, therefore, has a population of 130.3 per square mile of area and 78.7 per mile of road, with 1.65 miles of road per square mile of area. Of the population in 1910, 49.2 per cent, or 637,154, was rural, thus indicating a rural population of 38.71 per mile of road.

By an act of the legislature of 1908, as amended, the State roads commission was created and consists of the governor, ex officio, and five members appointed by the governor. The chairman is designated by the governor. The commission elects a secretary and employs a chief engineer, assistant engineers, and other necessary help. The commission must select, construct, improve, and maintain a general system of State roads in and through all of the counties of the State. It is authorized, in carrying out its duties, to take over, by purchase or condemnation, turnpikes forming a section of a main road to be improved by it. The construction and improvement of all State roads or parts thereof are required to be done under the supervision and subject to the approval of the commission, and in accordance with plans and specifications prepared by the chief engineer and approved by the commission. Where the cost of any work on a State road will exceed \$500, it shall be let under contract by the commission.

The commission is authorized to contract with the board of commissioners of any county to grade, maintain, and repair, and to more fully construct, the State roads within the borders of such county. The commission is authorized to establish stone-crushing plants, located at such points as to secure most economical water or other transportation, and to work State convicts in operating the same. The use of State convicts in road and bridge construction and maintenance work is also authorized. The commission is empowered to make such regulations and orders as it may deem necessary for the preservation of State roads and to regulate the use of same by traction engines and such other vehicles or conveyances as produce more than ordinary wear thereon.

The State road system, which includes State roads paid for entirely by the State, State-aid roads paid for by the State and counties jointly, and turnpikes purchased by the State, comprises 1,178.22

miles. All funds for the building of State roads are provided by State bond issues. The State roads commission is required to maintain all State roads and is authorized to adopt such method therefor as it may deem best, and to employ necessary engineers, assistants, and other employees. A State tax of 1 cent on each \$100 of taxable property is levied to provide a fund for the maintenance and repair of State roads. This fund is supplemented by 80 per cent of the net revenues derived from the registration and licensing of motor vehicles.

Provision is made for the granting of State aid to counties. Application for State aid in the improvement of any roads in a county shall be made by the county board of commissioners to the State roads commission. The commission shall cause necessary surveys, plans, and specifications to be made when such State aid work is approved and undertaken. The work is done by contract let by the county board of commissioners after due advertisement, subject to the approval of the State roads commission. The commission has immediate supervision of work done under contracts. Roads so improved are thereafter county roads and the county is required to maintain them to the satisfaction of the State roads commission, and any county failing to so maintain such roads shall not thereafter receive any State aid. In case of neglect on the part of the county to so maintain such roads, five taxpayers may apply to the circuit court for a writ of mandamus to compel the county commissioners to maintain the road.

Where State-aid work is undertaken, one-half of the cost thereof is to be paid by the State and one-half by the county, but no county shall receive in any year a larger proportion of the total amount appropriated for State aid that year than the proportion which the then existing miles of public roads in said county bears to the then existing total mileage of public roads in all counties of the State applying for State aid, unless an unallotted balance remains, in which event, said balance shall be apportioned in the same manner as the original appropriation among the counties which have not received the full amount of State aid for which application has been made. State-aid funds are provided by direct appropriations from the State treasury.

Jurisdiction over all county road and bridge matters is vested in the respective boards of county commissioners, who appoint road supervisors in those counties having road supervisors and may, when they shall deem it to the public interest, appoint an engineer to supervise and direct all road and bridge construction and repair work. All applications for opening, altering, or closing public roads are required to be by petition to the county board of commissioners.

No general road or bridge tax levy is provided in any of the counties, the levy varying in each county as determined by the county board

of commissioners and as fixed by the legislature at each session. There is no general road-bonding law in Maryland, road bonds issued in the several counties being under special authorization of the legislature and generally after an election thereon. Most of the counties work their convicts on the public roads.

REVENUES APPLIED TO ROADS AND BRIDGES.

In 1914 the total revenues applied to roads and bridges amounted to \$6,000,652.03, comprising the following items: general county road tax, \$1,047,043.99; miscellaneous revenues, \$816,282.68; expenditures from State appropriations and State bond issues applied to State roads, \$3,713,279; contributions by counties spent under State supervision on State-aid roads, \$309,504; expenditures from county bond issues, \$114,542.36.

In 1904 the total revenues applied to roads amounted to \$873,470.50, thus showing that in the 10-year period revenues for this purpose increased \$5,127,181.53, or 586.9 per cent. This is the largest increase in revenue reported for any Southern State. Detailed information showing tax rates and receipts from taxation for the various counties is shown in Table 14.

BOND ISSUES.

On January 1, 1915, the total county bonds outstanding amounted to \$443,700. During the year 1914, \$114,542.36 was expended from bond funds and \$26,500 of road bonds were retired. Information showing bond issues by counties is presented in Table 29.

On January 1, 1915, State bond issues amounting to \$12,410,000 were outstanding. These bonds were issued for the purpose of building a system of State roads. The amount of State bonds outstanding, the interest rate on each group of bonds issued, the date of maturity, and the character of the bonds is presented in Table 29a.

ROAD MILEAGE.

At the close of the year 1914 there were 16,458 miles of public road in the State, of which 2,489.26 miles, or 15.1 per cent, were surfaced. Of the surfaced roads, 488.70 were macadam, 1,042.31 bituminous macadam, 189.34 concrete, 243.95 gravel, 455.96 shell, and 69 sand clay.

In mileage of surfaced roads, Baltimore County stands first with 574 miles, or 47 per cent; Dorchester County second, with 215.43 miles, or 30.4 per cent; Montgomery County third, with 197.04 miles, or 23.8 per cent; Anne Arundel County fourth, with 181 miles, or 33.2 per cent; and Washington County fifth, with 152 miles, or 21.5 per cent. Every county in the State reported some surfaced roads.

At the close of 1909 Maryland had 2,142.30 miles, or 12.77 per cent, of surfaced roads, thus indicating that in the 5-year period 346.96 miles were surfaced. Information showing the total mileage and the mileage of surfaced roads in the various counties is contained in Table 44.

MISSISSIPPI.

Mississippi has a land area of 46,362 square miles, a total road mileage of 45,779, and a population, according to the 1910 census, of 1,797,114. The State, therefore, has a population of 38.76 per square mile of area and 39.25 per mile of road, with 0.99 miles of road per square mile of area. Of the population in 1910, 88.5 per cent, or 1,589,803, was rural, thus indicating a rural population of 34.72 per mile of road.

In 1916 a State highway commission was created to consist of three members, one from each supreme court district, appointed by the Governor with the advice and consent of the State senate. Each member of the commission is to serve for a term of six years. The State highway commission elects a State highway engineer, who is required to be a competent civil engineer, experienced and skilled in highway construction and maintenance. The State highway engineer is authorized to appoint, subject to the approval of the commission, necessary clerical and engineering assistants. The work of the commission is mostly of an educational and advisory nature.

The board of supervisors in each county has jurisdiction over the roads, bridges, and ferries therein. It is required to divide the public roads into convenient links and annually appoint one overseer for each link. It is the duty of the overseer to keep in good repair the roads under his charge and to erect such necessary bridges thereon as may be built and kept in repair conveniently by the labor of the hands assigned to him. The supervisor of each district in the several counties has, and is required to exercise, general supervision over the public roads of his district. The board of supervisors in each county may employ a competent person to serve as road and bridge commissioner.

Various provisions of law exist authorizing the building and maintaining of roads by contract to be let by the board of supervisors. Special road districts may be created by the boards of supervisors on petition of a majority of the property owners, or the owners of a majority of the property, in the territory to be embraced therein, and an engineer appointed to have charge of the road improvements therein, the cost of which improvements shall be met by benefit assessments on all real property in the district. Various other methods exist under the law for creating road districts, for raising

road funds therein, either by a tax levy or a bond issue, and for appointing officials, under different designations or titles, to have charge of road improvements to be made therein. The boards of supervisors may require adjoining road districts to connect their improved roads, one with the other, and may apportion the cost equitably between the districts. If a road district shall have improved its roads it may turn such improved roads over to the county and they shall be maintained thereafter by the board of supervisors.

The authorities of any city, town, or village may, if they deem it necessary or to the interest of such city, town or village, extend aid in the improvement of any road leading thereto and as far therefrom as may be deemed proper. A bridge over a stream which divides one county from another shall be constructed jointly by the boards of supervisors of such counties, and any municipality which will be benefited by the building of such bridge may join the counties in its construction.

The board of supervisors may levy an annual road tax of not exceeding $\frac{1}{10}$ mill on all taxable property in the county, but the taxes so levied and collected in any municipality which maintains its own streets shall be divided equally between the county road fund and the municipal street fund. Where the roads of a county, or any portion thereof, are worked under contract, an ad valorem tax of not to exceed 3 mills on \$1 may be levied on all taxable property in the county or such portion thereof. The board of supervisors may impose a tax on property contiguous to a shell, macadam, or gravel road, in addition to the other road taxes, for the purpose of constructing or maintaining such roads, when such property will be materially enhanced in value by such improvement.

Where county bonds are issued for the purpose of building a system of intercounty highways, the board of supervisors shall appoint a "county highway commissioner," who shall, subject to the approval of the board, employ a civil engineer and lay out, let to contract, and supervise the construction and maintenance of the roads to be improved with the proceeds of such bond issue. A number of provisions are made for the appointment of special commissioners, highway commissioners, or officers under other designations or titles where road bonds are issued or funds are provided otherwise for road improvements.

Road bonds may be issued by any county in an amount which will not make its indebtedness exceed 10 per cent of the assessed value of taxable property therein. Before bonds are issued, however, the board of supervisors shall give three weeks' notice of intention to issue such bonds and that a meeting will be held for that purpose, and if on or before such meeting there should be filed with the clerk of such board a petition signed by 20 per cent of the qualified electors

of the county against the issuance of said bonds, the proposition shall then be submitted to an election, and a majority vote of those voting shall be necessary to authorize such bond issue. Bonds of any road district may be issued in the same manner.

Where county or district road bonds are issued, it is required that a tax shall be levied adequate for the purpose of maintaining the roads constructed with the proceeds of the bonds issued.

All male persons between 18 and 50 years of age, not exempt by law, are liable to work on the roads not exceeding eight days, or to pay in lieu thereof the sum of \$3. The working of county convicts on public highways is authorized by law. Also, to a limited extent, State convicts may be so worked.

REVENUES APPLIED TO ROADS AND BRIDGES.

There are 18 counties in Mississippi from which it was impossible to obtain information on the subject of road taxation and revenues. The total receipts in the 62 counties furnishing complete information amounted to \$1,479,417.01, of which \$1,086,564.10 was obtained from general taxation in counties, beats and districts, \$31,405.55 from automobile registration fees, \$321,947.36 from per capita taxation, while \$39,500 represented the cash value of the statute labor tax.

Based on reports received, the total receipts from taxation for the whole State should be approximately \$1,908,925. The expenditures from bond issues during 1914 amounted to \$2,051,452.71, which makes a grand total received from taxation and bond issues and applied to roads during the year of approximately, \$3,960,377.

In 1904 the total expenditures for this purpose amounted to \$1,675,485.45, thus showing an increase during the 10-year period of \$2,284,891.55, or 136.3 per cent. Information showing receipts from taxation for counties which furnished reports is contained in Table 15.

ROAD AND BRIDGE BONDS.

The total road and bridge bonds issued by counties, beats and districts, outstanding on January 1, 1915, amounted to \$8,327,172, the expenditures from bond funds during 1914 amounting to \$2,051,452.71. In 1914 a total of \$40,000 of bonds previously issued were retired, \$1,225,500 were voted, and \$1,778,500 were sold. The bonds sold during 1914 bear from 5 to 6 per cent interest and run from 10 to 30 years. Detailed information in regard to bond issues by counties, districts and beats is contained in Table 30.

ROAD MILEAGE.

At the close of the year 1914, Mississippi had 45,779 miles of public roads, of which 2,133.35 miles, or 4.66 per cent, were surfaced. Of the surfaced roads, 1,281.10 miles were surfaced with gravel, 604.25 with sand-clay, 114 with shell, 86 with macadam, 29.5 with bituminous macadam, 14 with concrete, 4 with slag, and 0.5 with burnt clay.

In mileage of surfaced roads Lowndes County stood first, with 223 miles, or 54.65 per cent; Lee County, second, with 157 miles, or 50.32 per cent; Monroe County, third, with 150 miles, or 23.07 per cent; Lauderdale County, fourth, with 146.75 miles, or 18.37 per cent; and Hinds County, fifth, with 110 miles, or 12.79 per cent. Noxubee County had 103 miles and Copiah County 100 miles of surfaced roads, while 38 counties reported no surfaced roads. The surfaced and drained earth roads amounted to 13,686 miles.

In 1909 Mississippi reported 39,619 miles of public roads, of which 342.25, or 0.86 per cent, were surfaced. It thus appears that in the 5-year period 1,791.1 miles of road have been surfaced. Detailed information in regard to road mileage in the various counties is contained in Table 45.

NORTH CAROLINA.

By JOSEPH HYDE PRATT, *State Geologist and Secretary North Carolina Highway Commission, and Collaborator United States Office of Public Roads and Rural Engineering.*

North Carolina has a land area of 48,740 square miles, a population, according to the 1910 Census, of 2,206,287, and a total road mileage of 50,758. The State, therefore, has a population of 45.3 per square mile of area and 43.5 per mile of road, with 1.04 miles of road per square mile of area. Of the population in 1910, 85.6 per cent, or 1,887,813, was rural, thus indicating a rural population of 37.19 per mile of road.

From the coast lowlands westward to the mountains for a distance of over 500 miles there is great variation in topography. The conditions make for complex problems, so that each section has its own, especially with regard to location and surfacing materials. Thus it is found advisable to use macadam, gravel, sand-clay, or topsoil. Material for making sand-clay¹ road is abundant, and such roads meet the traffic requirements over a large portion of the State.

All the road work in North Carolina is directed by county or township officials. Until recent years all road-tax levies were made by the county commissioners and the funds were spent under their direction. Within the past three years, however, especially where road bonds have been issued, special road commissions have been

¹ Sand-clay includes gravel and topsoil.

appointed. During 1914 the road funds of the State were accordingly administered by the county commissioners, county road commissioners, township road commissioners or trustees, or other local officials.

No work has been done directly under the State, except such educational work and engineering assistance as could be rendered by the small annual appropriation of \$5,000 allotted for that purpose to the highway department of the North Carolina Geological and Economic Survey. The supervision of the construction of the Hickory Nut Gap Road and of a section of the Central Highway in Madison County was assigned to this department by the legislature of 1913. The use of State convicts for road work also was authorized by act of October 13, 1913.

A State highway commission was created by act of March 5, 1915, to consist of three citizens of the State to be appointed by the governor, the State geologist, and a professor of civil engineering each from the University of North Carolina and from the North Carolina Agricultural and Mechanical College. The commission is required to appoint a State highway engineer. An annual appropriation of \$10,000 is made to enable the commission to give engineering advice and assistance to the various counties.

The Mecklenburg law of 1879, which was repealed in 1881, has been reenacted and can be adopted now as the road law of any county by a vote of the county commissioners, on petition signed by a number of the freeholders in the county. It provides for working the public roads partly by the old labor system and partly by taxation. Counties may also work their convicts on their public roads. Prior to the passage of that law all road work was done by the free-labor system, which is still in vogue in a number of counties.

The general assembly of 1913 passed many acts relating to the issuing of road bonds by counties and townships. There was a wide variation in the methods authorized for issuing bonds. It can be done by election on a set date, by election on petition to the county commissioners, or directly by the county commissioners without vote or petition. One general law authorizes any township, except in certain counties, upon petition of one-fourth of the qualified voters of the township, to vote road bonds not exceeding \$50,000.

REVENUES APPLIED TO ROADS AND BRIDGES IN 1914.

The total revenues applied to roads and bridges during the calendar year 1914 amounted to \$5,215,490.78 and comprised the following items: receipts from regular county and township taxes, \$1,808,679.85; automobile and dog taxes and private subscriptions, \$272,155.43; bridge tax, \$89,525.50; cash value of statute labor tax, \$610,130; appropriation by the legislature for road investigations

and educational work by the geological and economic survey, \$5,000; and estimated expenditure of \$2,430,000¹ from county and township road and bridge bonds issued and sold during the years 1913 and 1914.

The total expenditure for public roads and bridges from taxation and bond issues during the year 1904 amounted to \$1,358,687, thus showing that expenditures increased \$3,856,803.78, or 283.8 per cent, in the 10-year period.

The total receipts from taxation applied to roads and bridges are shown by counties and townships in Table 16.

ROAD AND BRIDGE BONDS.

The total county and township road and bridge bonds outstanding on January 1, 1915, amounted to \$8,955,300. In 1914 a total of \$1,119,500 bonds were voted and \$2,709,000 sold.

No exact information is available to show how much was expended from bond issues in 1914, but the North Carolina Geological and Economic Survey estimates that this amounted to \$2,430,000. This expenditure was from bonds authorized and sold during the years 1913 and 1914.

The total amounts of road and bridge bonds outstanding on January 1, 1915, and the amounts voted and sold during 1914 are shown in Table 31.

ROAD MILEAGE.

At the close of 1914 North Carolina had 50,758 miles of public roads of which 6,003.75 miles, or 11.82 per cent, were surfaced. Of the surfaced roads 1,111 miles were macadam, 529 gravel, 4,313.5 sand-clay, 9 bituminous macadam, 1.25 concrete, and 40 miles not classified.

In mileage of surfaced roads Mecklenburg County stood first with 385 miles, or 38.5 per cent; Iredell second, with 265 miles, or 37.85 per cent; Richmond third, with 250 miles, or 41.66 per cent; Moore fourth, with 230 miles, or 38.33 per cent; Guilford fifth, with 220 miles, or 22 per cent; Franklin County has 210 miles, or 42 per cent; Wake County had 202.25 miles, or 16.85 per cent, and Wayne County has 210 miles, or 21 per cent. Twenty counties reported no surfaced roads. The total of graded and drained earth roads reported amounted to 4,181 miles. In 1909, 2,313 miles, or 4.79 per cent, were surfaced. In the 5-year period, 1909-1914, 3,690.75 miles were surfaced.

The mileage figures for the various counties are presented in Table 46.

¹ Information as to expenditure from bond issues was taken from Circular No. 105, issued July 5, 1915, by the North Carolina Geological and Economic Survey.

OKLAHOMA.

Oklahoma has a land area of 69,414 square miles, a total road mileage of 107,916 miles, and a population, according to the 1910 Census, of 1,657,155. The State, therefore, has a population of 23.87 per square mile of area and 15.36 per mile of road, with 1.55 miles of road per square mile of area. Of the population in 1910, 80.7 per cent, or 1,337,000, was rural, thus indicating a rural population of 12.38 per mile of road.

In 1911, the legislature passed an act creating a State highway department and provided for its maintenance by a registration fee of \$1 imposed upon each automobile in the State. A law was enacted in 1915 which created a new department of highways with enlarged powers and more adequate funds. This new law became effective July 1, 1915.

Owing to the reorganization of the State highway department, it it was not practicable to obtain road mileage and revenue statistics for the year 1914. It, therefore, was found necessary to wait until the new department was organized and could undertake the work of gathering the necessary information. For that reason the data contained in this bulletin relating to Oklahoma are for the year 1915, and were collected by W. P. Danford, assistant State engineer and collaborator for this office.

One commissioner, appointed by the governor, by and with the advice and consent of the senate, and known as the commissioner of highways, is in charge of the department of highways. The commissioner of highways is vested with the power of general supervision over all matters relating to State highways, including the preparation of plans, specifications, and estimates, establishing standards for the construction of roads and bridges, giving engineering advice to local road officials, and collecting and compiling statistics relative to the roads and bridges throughout the State. He is authorized, with the consent of the governor, to appoint a State engineer, who is required to be a civil engineer of established reputation and qualified in road and bridge construction. The commissioner may also appoint, with the consent of the governor, necessary assistant engineers and clerical help.

The law provides for the appointment of a county engineer by the board of commissioners of each county. Such engineer is required to pass an examination held by the department of highways. He is required to report to the State engineer upon all matters relating to highways and bridges in his county. His salary is paid from the State road construction fund and the road and bridge fund.

Where township organization is retained, the township board of each township is required to select, annually, the roads to be dragged,

known as draggable roads. Each township shall employ a superintendent of its road system. He has general supervision of all dragging and repair work. A drag tax of not more than 2 mills is authorized, and dragging may be let to contract.

It is required by law that not less than 10 per cent nor more than 15 per cent of the total mileage of main traveled roads in the State shall be designated by the boards of county commissioners, subject to approval by the department of highways, as a State road system. The board of county commissioners and the county engineer are charged with the duty of repairing and dragging the State road system.

An ad valorem tax of one-fourth of 1 mill is collected in the State and credited to the State highway construction fund. Each county retains its own share in this fund. Counties which make the required levy and otherwise comply with the law by having the plans and specifications approved by the department of highways, shall be entitled to receive all moneys to their credit in the State highway construction fund. The county excise board in each county is empowered to levy a tax of one-fourth of 1 mill on all property subject to an ad valorem tax in the county, the proceeds of which constitutes the county road construction fund, which is used in the construction and maintenance of county highways.

The fees required for the registration and licensing of motor vehicles are collected by the department of highways. Ten per cent of the proceeds of such fees is paid into the general fund of the State and 90 per cent is paid to the treasurers of the respective counties on the basis of the amounts collected therein. The county treasurer is required to pay to the treasurer of any city of the first class or operating under a charter form of government in such county 25 per cent of all fees originally paid by residents of any such city. The residue shall be placed to the credit of the county road maintenance fund.

All able-bodied males between the ages of 21 and 50 years are required to work four days on the roads annually or to pay \$5. The law also provides for the working of State and county convicts on the public roads.

The various townships are authorized to issue highway and bridge bonds, provided that the aggregate amount of indebtedness thus created shall not exceed 5 per cent of the taxable property in the township. Counties are also authorized to issue bridge bonds.

REVENUES APPLIED TO ROADS AND BRIDGES.

The total revenues applied to roads and bridges during the calendar year 1915 amounted to \$2,112,680.80. These revenues included the following items: general county and township tax, \$1,859,572.09;

cash value of statute labor tax, \$95,288; other revenues applied to roads, \$147,820.71; funds derived from automobile-registration fees, \$1 per car, and used for the support of the State highway department, \$10,000. It was impossible to secure complete information from the various counties in regard to the statute labor tax, and the amount given under that heading probably is much less than actually was realized.

In 1904 the total revenues applied to roads amounted to \$774,775.59 which comprised \$447,319.59 derived from property taxes and saloon licenses, and \$327,456 from statute labor tax. It will thus be seen that the revenues for roads increased during the 11-year period \$1,337,905.21, or 172.6 per cent.

The receipts from taxation for road and bridge purposes are shown in Table 17.

BOND ISSUES.

It was not practicable to obtain statistics regarding bond issues for the year 1914. At the close of the calendar year 1913 there was a total outstanding road and bridge bond indebtedness amounting to \$1,440,000.

ROAD MILEAGE.

The total of all public roads in Oklahoma at the close of 1915 amounted to 107,916 miles, of which 121.6 miles, or 0.11 per cent, were surfaced. Of the surfaced roads, 6.7 miles were macadam, 3 miles bituminous macadam, 6.9 miles gravel, and 105 miles sand clay. Most of the counties reported a smaller mileage of surfaced roads for 1915 than for 1909, the total decrease for the State for the 6-year period being 239.4 miles. This is due to the fact that a number of the counties reported surfaced roads in 1909 which were not actually surfaced.

The mileage statistics are shown by counties in Table 47.

SOUTH CAROLINA.

South Carolina has a land area of 30,495 square miles, a total road mileage of 42,226, and a population according to the 1910 census of 1,515,400. The State has a population of 49.7 per square mile of area and 35.9 per mile of road, with 1.38 miles of road per square mile of area. Of the population in 1910, 85.2 per cent, or 1,290,568, was rural, thus indicating a rural population of 30.6 per mile of road.

The collection of road statistics was begun early in 1915 by the commissioner of agriculture, commerce, and industries, who acted as collaborator for this office. The data was reported to him by the county officials and checked and then rechecked in this Office, so as to secure as high a degree of accuracy as possible.

South Carolina has no State-highway department. The department of agriculture, commerce, and industries, however, has from

time to time collected information relating to the public roads of the State and has issued road maps, route books and charts, and has had signposts erected along some of the main traveled roads.

The control of the public roads, bridges, and ferries of the several counties is vested by general law in a county supervisor and a county board of commissioners. The county supervisors are elected for four years with a few exceptions where a shorter term is provided by special law. The county board of commissioners consists of the county supervisor, as chairman, and two commissioners, appointed by the governor upon the recommendation of the county delegation to the general assembly. In a few counties exceptions to the general law provide for more than two commissioners.

A number of counties operate under special laws. For instance, Aiken County is administered by a chief commissioner and advisory board, known as the county board of commissioners and composed of one district commissioner from each of four districts into which the county is divided. The chief commissioner is required to inspect the public roads of the county and consult and advise with each district commissioner as to their improvement and maintenance. The chief commissioner and advisory board apportion the county road fund among the various townships of the county in proportion to the number of miles of public road in each township, the amount so apportioned to be expended by the district commissioners, respectively. A number of counties have their roads and bridges under the jurisdiction and management of a highway commission, and a few counties are authorized to employ a county road engineer.

County boards of commissioners are authorized to adopt the contract system of working roads and to let contracts to the lowest responsible bidders. If the county board of commissioners conclude to work the roads by the labor of those liable to road duty, they appoint overseers in each township. In counties where township board of commissioners exist overseers are appointed by the township board. In counties where the public roads are worked by those liable to road duty, or in which the roads in any highway district are so worked, the county supervisor and the board of county commissioners divide the highways into suitable sections of not less than 2 nor more than 5 miles each, and where not worked by contract appoint an overseer for each section. In counties where township board of commissioners exist they shall, subject to the approval of the county board of commissioners or the county supervisor, divide their respective townships into suitable districts and elect, at their annual meeting, from the qualified electors of the township one overseer for each district. District overseers, when required by the county board of commissioners, call out the hands assigned to their respective sections for the purpose of working the roads and bridges,

and they may require each hand to bring with him necessary implements for doing such work.

All male persons are required to perform work on the roads each year or pay a commutation tax in lieu thereof. The age limit within which persons are liable to this road duty in the different counties varies from between 18 and 21 to 50 and 55 years and the number of days work required each year varies from 2 to 12. The rate of commutation varies from \$1 to \$3 per day. Where road work is let to contract and persons liable to road duty are assigned by the county supervisor or the county board of commissioners to work under such contract, the contractor shall receive such persons and utilize their labor and allow to the county board of commissioners such per diem therefor as may be agreed upon. The per diem so allowed shall be credited on the amount due such contractor by the county.

The county board of commissioners is authorized to levy annually not to exceed 1 mill on all taxable property of the county to constitute a part of the county road fund. The county boards also are authorized, when so requested by written petition of two-thirds of the freeholders of a township, to levy not to exceed 1 mill on all taxable property in the township for road purposes. It also is provided by law that the board of county commissioners, when petitioned in writing by one-fourth of the resident electors of a township and a like proportion of the resident freeholders thereof over 21 years of age, may order the township board of assessors to hold an election at which only such electors as return real and personal property for taxation may vote, to determine whether or not an additional levy of not to exceed 2 mills may be made in such township. A majority vote of those voting is necessary to authorize such additional levy, and when so authorized the said board of county commissioners shall levy same for 2 years, and the proceeds thereof shall be used for road purposes.

It is also provided that any person, firm or corporation cutting or severing from the soil standing timber, for sale or manufacture within or without the State, shall return the value of all such timber cut during any calendar year for taxation during the succeeding year as other personal property, and one-half the revenue derived therefrom shall go to the public road fund.

There is no general law authorizing the issuance of road and bridge bonds. Such bonds when authorized are by special acts of the legislature.

REVENUES APPLIED TO ROADS AND BRIDGES.

The total revenue applied to roads and bridges for the year 1914 amounted to \$1,024,480.37 and comprised the following items: general county road and bridge tax, \$717,843.07; commutation

tax and miscellaneous revenues, \$214,512.30; cash value of statute labor tax, \$58,125; expended from bond issues, \$34,000.

The total expenditures for roads and bridges for the year 1904 amounted to \$745,701.50, thus showing that during this 10-year period the revenues increased \$278,778.87, or 37.4 per cent. Information showing tax rates and receipts from taxation for the various counties is contained in Table 18.

ROAD AND BRIDGE BONDS.

The total road and bridge bonds outstanding on January 1, 1915, amounted to \$460,000, of which \$75,000 were voted and sold during the year 1914. The expenditures from bond issues during the year 1914 amounted to \$34,000. Information regarding the South Carolina bond issues is presented by counties and townships in Table 32.

ROAD MILEAGE.

According to the reports received, South Carolina had, at the close of 1914, 42,226 miles of public road of which 3,270.5 miles, or 7.74 per cent, were surfaced. Of the surfaced roads, 3,101 miles were sand-clay, 85 miles gravel, 53.5 miles shell, 27.5 miles macadam, and 3.5 miles bituminous macadam.

In mileage of surfaced roads the reports indicate that Anderson County stands first, with 500 miles, or 41.39 per cent; Aiken County second, with 350 miles, or 27.40 per cent; Florence County third, with 225 miles, or 19.56 per cent; Richland County fourth, with 202 miles, or 26.86 per cent; and Darlington County fifth, with 200 miles, or 20 per cent. Eight other counties reported 100 miles or over of surfaced road and 7 counties reported no surfaced roads.

In 1909 South Carolina reported 32,075 miles of public road of which 3,534.75 miles, or 11.02 per cent, were reported as having been surfaced. The 1914 figures were secured and checked by the Commissioner of Agriculture of South Carolina, and it is believed that they are as accurate as it is possible to obtain at present. Information showing the total mileage and mileage surfaced in the various counties is contained in Table 48.

TENNESSEE.

Tennessee has a land area of 41,687 square miles, a total road mileage of 46,050, and a population, according to the 1910 census, of 2,184,789. The State, therefore, has a population of 52.4 per square mile of area and 47.44 per mile of road, with 1.10 miles of road per square mile of area. Of the population in 1910, 79.8 per cent, or 1,743,744, was rural, thus indicating a rural population of 37.86 per mile of road.

A State highway commission and a State highway department were created by the legislature in 1915. The State highway commission consists of six members, three of whom are appointed by the governor, and the other three are ex officio members—the State geologist, the dean of engineering of the University of Tennessee, and the governor. The State highway commission is required to elect one of its members chairman and appoint a secretary who must be experienced in road building and maintenance. The State highway department is required to designate a system of roads connecting the county seats of the several counties in the State and expend the State-aid fund, but otherwise its work is of an educational and advisory nature. Ten per cent of the net revenues from the registration and licensing of motor vehicles is applied to the maintenance of the State highway department; the remaining 90 per cent is used by the department in maintaining State highways.

The county courts of the several counties have jurisdiction over all matters pertaining to roads and bridges. The constitution provides that the different counties shall be laid off, as the general assembly may direct, into districts of convenient size so that the whole number in each county shall not be more than 25, or 4 for each 100 square miles of area. Two justices of the peace are elected in each district by the qualified electors. The county court is composed of the justices of the peace and the county judge as chairman. The county court is divided into a quarterly and a monthly court.

The county court, at its January term every odd year, is required to divide the county into one or more road districts and elect a road commissioner for each district. Each road commissioner has control of the highways and bridges and of the overseers or contractors in his district, and directs all road work done therein. The road commissioners appoint the road overseers. Each overseer has charge of not less than one nor more than 5 miles of road. Any county court, a majority of the justices of the peace assenting, may appoint three commissioners authorized to employ engineers and other necessary help to survey, inspect, classify, lay off for improvement, and prepare plans, specifications and estimates for such roads in the county as it is desired to have improved, and report thereon with recommendations to the county court. The quarterly court of any county may employ a competent person to superintend the construction and repair of county buildings, bridges, levees, etc. The quarterly court also is authorized to let any road or section of road to contract, in which event the laws applicable to overseers in working the hands assigned to such roads shall apply to the contractors.

County and municipal corporations may unite in the building and regulation of bridges over any stream running by or through such municipality. The county courts are required at their January term

each year to appoint three superintendents of turnpikes whose duty shall be to inspect turnpikes and toll bridges and see that they are kept in repair. The county judge also is made *ex officio* superintendent of turnpikes.

Under the general law authorizing counties to issue road bonds the county court may divide the county into not less than three nor more than eight road districts and appoint one road commissioner for each district; but the county court may appoint instead three road commissioners from the county at large. In either event the road commissioners so appointed shall be the road commissioners of the county and shall have supervision of the construction of the roads provided for by the county court, with authority to employ a competent highway engineer and, if necessary, an assistant engineer. Numerous special road laws have been enacted and are in force in many counties. These special laws vary the method of road administration somewhat from that provided by the general law.

The county courts are authorized to impose a highway tax of not less than 5 nor more than 25 cents on each \$100 of assessed valuation of the county and on privileges not more than one-fourth of the assessment for county purposes. Two-thirds of the property tax may be worked out if the county court shall so decide. County courts of the various counties may issue road bonds in an amount with existing indebtedness not to exceed 10 per cent of the taxable valuation of the county when authorized by a majority vote, and in an amount, with existing indebtedness, not to exceed 15 per cent of the taxable valuation of the county when authorized by a two-thirds vote of those voting at an election held thereon. When bonds are voted, a tax necessary for interest and for retiring the bonds at maturity shall be levied and also a tax to create an annual maintenance and repair fund equal to 2 per cent of the amount of the bonds issued.

The county courts shall impose a highway labor tax of not less than four nor more than eight days each year on all males between 18 and 45 years of age not exempt by law. The highway labor tax so imposed may be commuted by paying 75 cents for each day of work so required. There is provision of law for the working of county and State convicts upon the public roads.

REVENUES APPLIED TO ROADS AND BRIDGES.

In 1914 the total receipts from taxation and bond issues applied to roads and bridges amounted to \$2,370,560.16, comprising the following items: general county tax, \$977,564.09; labor tax paid in money, \$18,133.63; cash value of statute labor tax, \$350,960; bridge tax and other revenues, \$245,595.92; and expenditures from bond issues, \$778,306.52. The total expenditures for these purposes in 1904

amounted to \$1,621,777.15, showing that in the 10-year period expenditures increased \$748,783.01, or 46.1 per cent.

Information showing receipts from taxation by counties for the year 1914 is contained in Table 19.

ROAD AND BRIDGE BONDS.

The total road and bridge bonds outstanding on January 1, 1915, amounted to \$6,898,276.89. In 1914 there was expended from bond issues \$778,306.52, retired \$128,421.11, voted \$486,500, and sold \$445,000 of road bonds.

Detailed information showing the bond issues by counties is contained in Table 33.

ROAD MILEAGE.

According to the reports received, Tennessee had at the close of 1914, 46,050 miles of public roads of which 8,102 miles, or 17.59 per cent, were surfaced as follows: 4,550.5 miles macadam, 2,788 gravel, 613 sand-clay, 148 miles bituminous macadam and bituminous-treated gravel, 2 miles concrete, and one-half mile brick.

In mileage of surfaced roads Shelby County stands first with 752 miles, or 55.62 per cent; Rutherford County, second, with 700 miles, or 63.63 per cent; Maury County, third, with 625 miles, or 55.55 per cent; Smith County, fourth, with 410 miles, or 91.11 per cent; Davidson County, fifth, with 375 miles, or 62.5 per cent; and Knox County, sixth, with 375 miles, or 37.5 per cent. There are 15 other counties which reported more than 100 miles of surfaced roads and there are 27 counties that reported no surfaced roads.

In 1909 Tennessee reported 5,353.5 miles, or 11.66 per cent of surfaced roads. A comparison of these figures will show that in the 5-year period, 1910-1914, inclusive, 2,748.5 miles were surfaced. Information showing the total mileage and mileage of surfaced roads by counties is contained in Table 49.

TEXAS.¹

Texas has a land area of 262,398 square miles, a total road mileage of 128,960 and a population, according to the 1910 census, of 3,896,542. The State has a population of 14.8 per square mile of area and 30.21 per mile of road, with 0.49 mile of road per square mile of area. Of the population in 1910, 75.9 per cent, or 2,958,438, was rural, thus indicating a rural population of 22.94 per mile of road.

¹ The collection of road statistics was begun early in 1915 by Dr. William B. Phillips, collaborator for this Office, and director of the bureau of economic geology and technology of the University of Texas. Subsequently, however, Dr. Phillips resigned his position at the university to take up work in another State. Mr. J. A. Udden, of the university, was then appointed collaborator, and the work was continued by him. A cooperative arrangement was also made whereby the assistance of Prof. R. L. Morrison, of the Agricultural and Mechanical College of Texas, was secured. In addition, extensive correspondence was conducted directly with various county officials, commercial organizations, and good-roads associations. Valuable assistance was rendered by Mr. D. E. Colp, secretary of the Texas Good Roads Association.

Texas has no State highway organization. Each county is divided into four precincts from each of which a commissioner is elected, with a term of two years, which commissioners, with the county judge, constitute the commissioners' court. The commissioners' court has general control and supervision over all roads, bridges and ferries in the county, and is authorized to appoint one road superintendent for the county or one for each commissioners' precinct, as it may determine. The road superintendent so appointed, subject to the direction of the court, shall have general supervision over all road and bridge work in the county or precinct, as the case may be. The commissioners' court of the several counties is required to divide the county into convenient road precincts and appoint a road overseer and apportion the road hands for each precinct. Each road overseer is required to work the roads in his precinct twice each year. The court also may employ not exceeding four road commissioners and define and fix the districts which each shall control. Each road commissioner, when employed, shall have control over all the overseers, road machinery, tools, implements and labor in his district.

The commissioners' court is authorized to levy annually a road and bridge tax of 15 cents on each \$100 of assessed property valuation. An additional levy of 15 cents on each \$100 may be made by the court when authorized by vote of a majority of the qualified property taxpaying voters of the county. Road and bridge bonds may be issued by any county or political subdivision or defined district thereof in an amount not to exceed one-fourth of the assessed value of the real property therein, when authorized by the vote of a two-thirds majority of the resident property taxpayers voting at an election called for that purpose.

All male persons between 21 and 45 years of age may be required to work on the roads not exceeding five days each year or to pay \$1 for each day of such work required of them. The law also authorizes the working of county convicts on the roads.

REVENUES AND BOND ISSUES.

In 1914 the total revenue and bond issue money applied to roads and bridges amounted to \$9,920,079.11, comprising the following items: county road and bridge tax, \$4,064,165.98; special taxes and miscellaneous revenues, \$678,582.38; cash value of statute labor tax, \$321,771.50; cash in lieu of labor, \$36,724; estimated expenditures for 29 counties not reporting, \$666,378.53; expenditures from bond issues, \$4,152,456.72.

The total revenue devoted to roads and bridges in 1904 amounted to \$4,138,157.49. Thus it appears that in the 10-year period the

revenues for these purposes increased \$5,781,921.62, or 139.7 per cent.

The revenues and tax rates for 1914 are shown by counties in Table 20.

ROAD AND BRIDGE BONDS.

On January 1, 1915, the total road and bridge bonds outstanding for various counties in Texas amounted to \$14,615,016.53. In 1914 there was expended on roads and bridges from bond issues \$4,152,-456.72, there was retired \$266,255, voted \$6,783,275.60, and sold \$3,119,990.60. Many of the bonds sold in 1914 bear 5 per cent interest, run for 40 years, and brought par or par and accrued interest. Detailed information showing the bond issues by counties is contained in Table 34.

ROAD MILEAGE.

At the close of 1914, according to the reports received, Texas had 128,960 miles of public roads, of which 10,526.79 miles, or 8.16 per cent, were surfaced. Of the surfaced roads, 511 miles were macadam, 5,258.98 miles were gravel, 3,490.48 sand-clay, and 1,265.33 miles were surfaced with other materials, including shell, bituminous macadam, concrete, and hard roads not classified as to type. This latter figure includes 181 miles of bituminous macadam, 740.45 miles of shell, and 11.25 miles concrete.

In the mileage of surfaced roads, Tarrant County stands first with 586.5 miles, or 53.98 per cent; Dallas County, second, with 522 miles, or 40.15 per cent; Bexar County, third, with 414.26 miles, or 40.15 per cent; Archer County, fourth, with 400 miles, or 26.66 per cent; and Ellis County, fifth, with 400 miles, or 20 per cent. There are 28 other counties having more than 100 miles of surfaced roads, and there are 129 counties which reported no surfaced roads.

At the close of 1909 Texas had 4,896 miles, or 3.80 per cent, of surfaced roads, which indicates that in the 5-year period, 1910-1914, inclusive, 5,640.79 miles were surfaced.

Information showing total mileage and mileage of surfaced roads in the various counties is contained in Table 50.

VIRGINIA.

By G. P. COLEMAN, *State Highway Commissioner.*

Virginia has a land area of 40,262 square miles, a total road mileage of 53,388 and a population, according to the 1910 census, of 2,061,612. The State has a population of 51.2 per square mile of area and 38.6 per mile of road, with 1.32 miles of road per square mile of area; of the 1910 population 1,585,083, or 76.8 per cent, was rural, thus indicating a rural population of 29.7 per mile of road. The eastern half of the State is broken up by the Chesapeake Bay and

its large tributary tidewater rivers and bays. Three large mountain ranges traverse the western section of the State from northeast to southwest. These natural subdivisions have presented many varying problems in road construction and maintenance.

In the extreme eastern sections sand and clay are the only local materials available for construction. In the middle eastern section there are large deposits of gravel and some small ledges of suitable stone. However, when it is necessary to build stone roads in either of these sections it is found advisable to ship in stone from Maryland, New York or the western sections of Virginia. In the middle sections—that is, east of the Blue Ridge Mountains—there are large gravel and soil deposits and varying quantities of suitable stone for macadam, concrete and bituminous roads. From the Blue Ridge west the majority of the roads constructed have, up to the present time, been water-bound macadam with some surface treatment.

HIGHWAY DEPARTMENT.

In 1906 the State highway department and State convict road force were established. Under this law the convicts and jail prisoners are furnished to the counties free of cost; that is, the State feeds, clothes and otherwise takes care of the men. They are placed on the road each day, and the county furnishes the necessary tools, teams and free labor to carry on the work systematically and economically. This divides the cost of construction about equally between the State and the county. At the present time there are 34 camps established in the State, employing from 1,800 to 1,900 men.

In addition to this, the State has appropriated from year to year about \$200,000 to be expended in counties in which convict labor is not being used. This fund is distributed to the counties according to the taxes paid into the State treasury and the counties have to meet it with an equal amount.

Under these two laws the State has assisted the counties in constructing approximately 3,600 miles of road in the past nine years, and between 300 and 400 bridges of varying length have been built. These roads, after construction, have been turned over to the counties and the districts of the counties for maintenance and in many instances they have been neglected entirely. All State money aid and convict labor work is done under the supervision and according to the specifications of the State highway department.

The legislature, at its last session, set aside the licenses received from automobiles for the maintenance of the roads which have been constructed with State aid, convict labor or county bond issues. This fund is to be met by a like amount to be appropriated from the county funds. Heretofore these funds have been used by the State in construction work.

COUNTY AND DISTRICT ORGANIZATIONS.

In the majority of the counties of the State the road work is done directly under the board of supervisors, elected by the people, one from each district. The number of districts in a county vary from three to nine. The supervisor of a district generally looks after the road and bridge work of his particular district. In some instances, however, the counties have special laws creating county road boards. These boards take over the road authority which the general law vests in the board of supervisors, and appoint either a county road superintendent or district road superintendent to supervise the construction of the roads and the bridges of the county as a whole, or of the individual district.

Another plan followed in some of the counties under special law is the formation of district road boards. These have control of the construction and maintenance of the roads in the several districts of the counties. These boards usually are composed of three citizens, as follows: A duly elected member of the board of supervisors, who acts as chairman; a road commissioner, and a clerk. The road commissioner takes the place of the district superintendent and has actual charge of the road force.

The board of supervisors of the county lays all levies for road and bridge purposes for both the county and the districts. These amounts, as collected by the treasurer, are credited either to the general county road or bridge fund, or to the district road or the district bridge fund, and can be expended only for purposes for which they were collected. From these funds the county takes the money with which to meet the State money aid or to supply the teams, tools, etc., to be used in connection with the convict labor.

In addition to the regular levy, the counties or districts are allowed to vote bonds for road and bridge improvement. These funds must be expended under the supervision of an engineer designated by the State highway department. The funds derived from general county or district levies remaining in the county or the district road and bridge fund, after setting aside the amount to meet the State money or convict aid, are used for the maintenance and upkeep of the road.

The information contained in these reports has been obtained by letters to the various county clerks and treasurers, supplemented by visits of the men connected with the State highway department to these counties, who got the information from members of the boards of supervisors, members of the county road boards and district road boards. The tables are checked finally by members of the department with reports of the county treasurers to the auditor of public accounts of the State. Much difficulty has been experienced, however, in getting accurate information as to the amount of money derived from road and bridge taxes on account of the change in the

State system of taxation which was put into effect in the early part of 1914. This has brought about a great deal of confusion and the figures given are not as satisfactory as it was hoped to have them.

The road mileage has been taken from the records in the county clerk's offices and obtained from road superintendents, commissioners, and members of the boards of supervisors. Figures relative to permanent work have been taken largely from reports of the highway department. A better and more satisfactory return as to the amount of finances possibly could be obtained from the reports of 1915 to the State auditor.

FUNDS FOR STATE ROAD PURPOSES.

There is no special State tax for road purposes. For the calendar year 1914 the State money aid, amounting to \$185,000, was appropriated from the general funds of the State to meet a like amount appropriated from the county revenues. The appropriation of \$160,000 for the maintenance of the State convict road forces was taken from the same source. This, together with the fees taken from the general fund for the maintenance of jail prisoners, amounting to \$49,066.83, makes a total of \$209,066.83 for this purpose. The automobile fund, which goes into the State-aid fund, amounted to \$116,188.65. These funds, together with an appropriation of \$26,500 for the maintenance of this department, make up the total appropriations for road purposes made by the State, amounting to \$536,755.88. In addition to this there was expended under the supervision of this department in road and bridge work, derived from county sources, \$1,404,349.81, thus making a total from all sources expended under the State highway department of \$1,941,105.69.

REVENUES APPLIED TO ROADS AND BRIDGES.

The total revenue available for expenditure in 1914 amounted to \$3,224,528.82, of which \$1,687,906 was derived from general county and district road taxes, \$999,866.94 from county and district bond issues, and \$536,755.88 from State appropriations.

The total expenditures for road and bridge purposes in 1904 amounted to \$687,751.06, thus showing in the 10-year period that expenditures increased \$2,536,777.76, or 368.8 per cent.

The tax rates for county and district roads and the amounts derived therefrom during 1914 are shown in Table 21.

ROAD AND BRIDGE BONDS.

The total road and bridge bonds outstanding on January 1, 1915, amounted to \$5,650,994.93. In the year 1914 a total of \$999,866.94 was expended from bond issues, and \$510,938.23 previously issued were retired. In the same year a total of \$366,000 new bonds was

authorized and \$452,100 were sold. Detailed information showing total bonds outstanding, expenditures from bond funds during 1914, bonds voted and sold in 1914, interest rate, term, and purchase price is shown by counties and districts in Table 35.

ROAD MILEAGE.

The total mileage of public roads in Virginia at the close of 1914 was 53,388, of which 3,909.57 miles, or 7.32 per cent of the total, were surfaced. Of the surfaced roads 1,177.89 miles were macadam, 255.77 bituminous macadam, 822.09 gravel, 1,511.65 sand-clay and topsoil, and 142.17 miles were surfaced with other materials, principally shell.

In mileage of surfaced roads Mecklenburg County stands first, with 315 miles, or 39.52 per cent; Chesterfield County second, with 202.5 miles, or 33.75 per cent; Rockingham County third, with 137 miles, or 8.32 per cent; Dinwiddie County fourth, with 124 miles, or 20.66 per cent; and Henrico County fifth, with 120.45 miles, or 13.38 per cent. Charlotte County has 106 miles, or 11.77 per cent, surfaced, and Greenville 100 miles, or 58.82 per cent. There are 21 counties in the State having not less than 50 nor more than 99 miles of surfaced road. Sixteen counties report no surfaced roads, but in 1904 there were 70 counties which reported no surfaced roads.

Fifteen counties reported a smaller mileage of surfaced roads for 1914 than for 1909. In spite of this decrease the reports show that in the 5-year period 2,006.82 miles of road have been surfaced. In 1909 the mileage surfaced amounted to 1,902.75, which represented 4.38 per cent of the total, thus indicating that the surfaced road mileage more than doubled in the 5-year period, 1909 to 1914.

Details showing the total mileage of all roads, the mileage surfaced, the per cent of the total surfaced, the increase in surfaced mileage over 1909, and the mileage of graded and drained earth roads in the various counties are presented in Table 51.

WEST VIRGINIA.

By A. DENNIS WILLIAMS, *Chief Engineer State Road Bureau and Collaborator United States Office of Public Roads and Rural Engineering.*

West Virginia has a land area of 24,022 square miles, a total road mileage of 32,024 and a population, according to the 1910 Census, of 1,221,119. The State, therefore, has a population of 50.8 per square mile of area and 38.1 per mile of road, with 1.33 miles of road per square mile of area. Of the population in 1910 81.3 per cent, or 992,877, was rural, thus indicating a rural population of 31 per mile of road.

The first road laws of the State were enacted in 1872 and revised in 1881. The legislature of 1907 provided for the office of State

highway inspector, whose duty it was to study the road conditions of the State and report to the governor. Prior to the meeting of the legislature in 1909 the governor appointed a commission to re-write the road laws, and at the legislative session of that year an act was passed establishing a department of the State government to be known as the office of public roads, and creating the office of State commissioner of public roads, all of which, however, was abolished in 1911.

In the legislative session of 1913 a law was enacted establishing the State road bureau, which consists of the professor in charge of the railroad and highway department of the State university, who is the chief road engineer and the chairman, the director of the experiment station at the State university, and two additional members appointed by the governor. The chief road engineer, with the approval of the State road bureau, is authorized to select such clerical and engineering help as may be necessary. Salaries and expenses in connection with the State road bureau are paid from the university funds, and from appropriations by the legislature.

The State road bureau has general supervision of the location, construction, and maintenance of all public roads in the State so far as may be consistent with the authority over said roads otherwise conferred by the constitution or statutes. It prescribes rules and regulations not inconsistent with law concerning the duties of road engineers and their employees, and aids county road engineers and their employees by giving advice and preparing plans and specifications for road and bridge work. A school of instruction for county road engineers is required to be held for at least 10 days each year by the State road bureau, and the county road engineers are required to attend and are authorized to receive from their respective counties the actual expenses incurred thereby.

The State road bureau is authorized to establish and maintain stone quarries, crushers, and brick kilns, and may employ the State convict road force in the preparation of road materials. The State convict road force also may be worked on the public roads.

County courts have jurisdiction over all matters pertaining to the public roads and bridges in their respective counties. The county court of each county may appoint some practical road builder or civil engineer as county road engineer. In the event the county court shall not appoint a county road engineer, it may appoint a competent man as road supervisor for each magisterial district. Upon petition of 50 legal voters of the county who are freeholders, the county court shall cause a vote to be taken upon the question as to whether there shall be appointed a county road engineer or one road supervisor for each magisterial district of the county. Each magisterial district is divided by the county

court into two or more road precincts, and the county road engineer, by and with the advice and consent of the county court, shall employ such agent or agents in these precincts as may be deemed necessary.

It shall be the duty of the county road engineer to divide, or cause to be divided, all of the county roads in the respective road precincts into sections not exceeding 2 miles in length, and let the same to contract. Each road supervisor shall divide his district into convenient road precincts, not exceeding 10 miles in length, and, after two weeks' advertisement, let the construction and repair of said roads by contract to the lowest responsible bidder for such time as the county court may direct.

The present law permits a maximum levy of 30 cents on the \$100 for county and district road purposes. A special bridge tax of 20 cents on the \$100 may be levied in counties that do not have a bonded indebtedness. In addition, there may be levied 5 cents on the \$100 of all taxable property in the county, or in lieu thereof 10 cents on each \$100 of taxable property in any magisterial district. Any county or magisterial district may issue bonds for road purposes when authorized by a three-fifths vote of those voting at an election called for that purpose, but the bonded indebtedness that may be created by any county or magisterial district shall not exceed 5 per cent on the value of the taxable property therein. The county court also may levy, for road purposes, a poll tax of \$1 on every male citizen over 21 and under 50 years of age. The working of county convicts on the public roads also is authorized.

REVENUES APPLIED TO ROADS AND BRIDGES.

The total revenues applied to roads and bridges in the fiscal year ended July 1, 1915, amounted to \$2,483,747, and comprised the following items: permanent road tax, \$656,594; bridge tax, \$463,487; general road tax, \$1,249,505; capitation tax, \$110,395; and appropriation for the maintenance of the State road bureau, \$3,766.

The total expenditures for the year 1904 amounted to \$893,285, thus showing that expenditures in a little over 10 years increased \$1,590,462, or 178 per cent.

In 1904 the statute labor tax still was in use, and of the total expenditure for that year for all road and bridge purposes, \$305,415 represented the cash value of this tax. In 1909 this tax was abolished. The receipts from taxation and the tax rates for permanent roads and general road purposes are shown by counties in Table 22.

ROAD AND BRIDGE BONDS.

It was impossible to secure information in regard to bonds outstanding January 1, 1915, or bond funds expended in 1914. From reports received it appears that the various counties and districts voted \$5,354,000 road and bridge bonds up to July 1, 1915. The bonds outstanding on that date, so far as could be ascertained, amounted to \$1,303,000.

The amount of bonds outstanding and the amount voted in each county up to July 1, 1915, are shown in Table 36.

ROAD MILEAGE.

At the close of the fiscal year 1914-15, West Virginia had 32,024 miles of public roads, of which 1,064.97 miles, or 3.3 per cent, were surfaced. Of the surfaced roads, 771.92 miles were macadam, 62.95 miles bituminous macadam, 121.1 miles brick, 18.5 miles concrete, 20.5 miles gravel, and 70 miles shale.

In surfaced road mileage Jefferson County stands first, with 280 miles, or 82.4 per cent; Ohio County second, with 204 miles, or 80 per cent; Berkeley County third, with 145 miles, or 31.8 per cent; Brooke County fourth, with 52 miles, or 29.2 per cent; and Mercer County fifth, with 42 miles, or 10.4 per cent. Twenty-eight counties had less than 10 per cent of the roads surfaced, and 22 counties had no surfaced roads. In 1904 there were 44 counties that reported no surfaced roads.

In 1909, 591.4, or 1.84 per cent, of the total were surfaced. It would seem therefore that in the period 1909 to 1914-15 a total of 473.6 miles were surfaced. The 1914-15 mileage statistics for the various counties are presented in Table 52.

APPENDIX.

TABLES SHOWING ROAD REVENUES AND EXPENDITURES.

Following are the tabular arrangements of the revenues applied to roads and bridges referred to in the foregoing text:

ALABAMA.

TABLE 7.—County revenue applied to roads and bridges in 1914.

County.	Taxation and revenues, 1914.		Statute labor road tax, 1914.			
	County road tax rate in cents per \$100.	Total revenue applied to roads and bridges.	Number of men who worked.	Average number of days worked.	Average daily wage of hired help.	Cash value of labor tax.
Autauga.....	\$0.25	\$11,600.00	1,200	10	\$1.00	\$12,000
Baldwin.....	.25	18,000.00				
Barbour.....		39,279.00				
Bibb.....		18,000.00				
Blount.....		97,000.00				
Bullock.....		23,000.00	300	10	.75	2,250
Butler.....		42,500.00				
Calhoun.....	.25	61,102.41				
Chambers.....	.25	18,340.00				
Cherokee.....		9,905.25				
Chilton.....	.25	12,000.00				
Choctaw.....	.25	9,500.00				
Clarke.....		8,200.00				
Clay.....		9,700.00	1,800	10	1.00	18,000
Cleburne.....	.15	3,524.94				
Coffee.....		20,000.00	1,250	10	1.00	12,500
Colbert.....		15,000.00				
Conecuh.....		18,100.00				
Coosa.....		11,000.00				
Covington.....	.25	21,000.00				
Crenshaw.....	.25	9,500.00				
Cullman.....		93,710.00				
Dale.....	.25	12,568.27				
Dallas.....	.25	35,212.50	3,000	10	.75	22,750
Dekalb.....		28,000.00				
Elmore.....		17,822.00				
Escambia.....	.25	18,856.00	2,600	3½	1.25	11,375
Etowah.....		25,400.00				
Fayette.....		23,900.00	100	10	1.00	1,000
Franklin.....	.25	17,000.00				
Geneva.....		10,000.00				
Greene.....		8,000.00				
Hale.....		8,000.00				
Henry.....		12,000.00				
Houston.....	.25	24,500.00				
Jackson.....		6,200.00				
Jefferson.....		360,020.00				
Lamar.....		8,328.15				
Lauderdale.....	.10	6,600.00				
Lawrence.....	.25	15,976.00				
Lee.....	.25	65,100.00	350	6	1.00	2,100
Limestone.....	.25	13,248.04				
Lowndes.....	1.50	24,286.02				
Macon.....		24,000.00				
Madison.....		112,600.00	12,000	6	1.00	72,000
Marengo.....	.25	24,000.00				
Marion.....	.10	9,800.00				
Marshall.....		65,000.00				
Mobile.....	.20	90,000.00				
Monroe.....		10,000.00	2,300	3½	1.00	8,050
Montgomery.....		253,410.00	10,000	7	1.00	70,000
Morgan.....		15,150.00				
Perry.....		33,755.00	8,000	5	1.00	40,000
Pickens.....		9,812.82				
Pike.....	.25	31,650.55				
Randolph.....		6,083.30				
Russell.....	.25	20,596.02				
St. Clair.....		23,000.00				
Shelby.....	.25	22,400.00	3,000	5	1.00	15,000
Sumter.....	.20	15,740.00				
Talladega.....		44,829.24				
Tallapoosa.....	.15	28,000.00				
Tuscaloosa.....		144,000.00				
Walker.....		125,000.00	500	4	1.50	3,000
Washington.....	.25	16,000.00	1,200	10	1.00	12,000
Wilcox.....		23,000.00			1.00	
Winston.....		30,000.00				
Total.....		2,488,805.51	47,600			302,025

¹ Includes 25 cents for road and bridge bonds.

ARKANSAS.

TABLE 8.—County revenue applied to roads and bridges, 1914.

County.	Total revenue applied to roads and bridges.	Amount obtained from general county tax of 3 mills per \$1.	Statute labor tax.			
			Number of men who worked roads.	Average number of days worked.	Average wage for hired help.	Cash value labor tax.
Arkansas.....	\$25,249.00	\$25,249.00				
Ashley.....	17,000.00	17,000.00				
Baxter.....	6,000.00	6,000.00				
Benton.....	21,000.00	21,000.00				
Boone.....	11,309.00	11,309.00				
Bradley.....	12,600.00	12,600.00				
Calhoun.....	9,000.00	9,000.00				
Carroll.....	11,233.00	11,233.00				
Chicot.....	16,092.00	16,092.00				
Clark.....	28,871.00	28,871.00				
Clay.....	19,000.00	19,000.00				
Cleburne.....	7,640.00	7,640.00				
Cleveland.....	7,999.00	7,999.00				
Columbia.....	13,100.00	13,100.00				
Conway.....	12,000.00	12,000.00				
Craighead.....	28,000.00	28,000.00				
Crawford.....	18,000.00	18,000.00				
Crittenden.....	36,000.00	30,000.00	1,000	3	\$2.00	\$6,000
Cross.....	24,000.00	19,000.00	1,000	4	1.25	5,000
Dallas.....	11,899.90	11,899.90				
Desha.....	14,040.91	14,040.91				
Drew.....	12,000.00	12,000.00				
Faulkner.....	19,000.00	11,000.00	2,000	4	1.00	8,000
Franklin.....	14,000.00	14,000.00				
Fulton.....	6,360.99	6,360.99			1.00	
Garland.....	29,000.00	29,000.00				
Grant.....	7,000.00	7,000.00				
Greene.....	19,948.68	19,948.68				
Hempstead.....	20,000.00	20,000.00				
Hot Spring.....	12,000.00	12,000.00				
Howard.....	4,946.00	4,946.00				
Independence.....	11,812.00	11,812.00				
Izard.....	7,086.00	7,086.00				
Jackson.....	21,500.00	21,500.00				
Jefferson.....	68,900.00	2 68,900.00				
Johnson.....	10,000.00	10,000.00				
Lafayette.....	10,000.00	10,000.00				
Lawrence.....	16,000.00	16,000.00				
Lee.....	34,750.00	3 16,000.00	2,500	7½	1.00	18,750
Lincoln.....	8,514.00	8,514.00				
Little River.....	14,000.00	14,000.00				
Logan.....	22,966.99	15,758.99	1,802	4	1.00	7,208
Lonoke.....	5,000.00	5,000.00				
Madison.....	9,000.00	9,000.00				
Marion.....	8,000.00	8,000.00				
Miller.....	14,011.00	12,011.00	1,000	2	1.00	2,000
Mississippi.....	24,000.00	24,000.00				
Monroe.....	5,822.00	5,822.00				
Montgomery.....	5,707.00	5,707.00				
Nevada.....	10,605.00	10,605.00				
Newton.....	4,431.87	3,984.45				
Ouachita.....	3,000.00	447.42				
Perry.....	9,000.00	3,000.00				
Phillips.....	28,000.00	9,000.00				
Pike.....	8,925.00	28,000.00				
Poinsett.....	19,813.00	8,925.00				
Polk.....	16,903.86	19,813.00				
Pope.....	12,000.00	13,407.86	874	4	1.00	3,496
Prairie.....	15,000.00	12,000.00				
Pulaski.....	207,000.00	15,000.00				
Randolph.....	19,000.00	4 162,000.00	7,500	4	1.50	45,000
St. Francis.....	10,500.00	11,000.00	2,000	4	1.00	8,000
Saline.....	13,000.00	10,500.00				
Scott.....	6,731.00	13,000.00				
Searcy.....	9,500.00	6,731.00				
Sebastian.....	51,000.00	9,500.00				
Sevier.....	12,900.00	51,000.00				
Sharp.....	7,000.00	12,900.00				
Stone.....	3,874.00	7,000.00				
Union.....	14,493.00	3,874.00				
Van Buren.....	26,152.38	14,493.00				
Washington.....	16,674.00	26,152.38				
White.....	16,084.62	16,674.00				
Woodruff.....	14,000.00	16,084.62				
Yell.....	15,750.00	14,000.00				
Total.....	1,362,696.20	1,259,242.20				103,454

1 Includes \$4,000 per capita tax.

3 Is commutation tax.

2 Includes \$20,000, county general fund.

4 Includes \$7,000, auto tax; and \$20,000, general fund.

DELAWARE.

TABLE 9.—County revenue applied to roads and bridges in 1914.

County.	Total.	County tax rate.	Amount obtained.	State aid.
		<i>Mills.</i>		
Kent.....	\$20,000	0.17	\$10,000	\$10,000
New Castle.....	103,000	(¹)	92,000	11,000
Sussex.....	26,628	1.5	16,628	10,000
Total.....	149,628	.....	118,628	31,000

¹ Appropriation.

In addition to the above a 2-mill tax was levied in Sussex County for road and bridge bonds, from which \$27,713.73 was derived.

FLORIDA.

TABLE 10.—County revenue applied to roads and bridges in 1914.

County.	Total revenue applied to roads and bridges.	General county tax.		Receipts from other sources.			
		Rate, mills per \$1.	Receipts.	Source.	Rate.	Receipts.	Total receipts.
					<i>Mills.</i>		
Alachua.....	\$33,093.02	3	\$23,275.56	{Auto licenses.....		\$2,000.00	\$9,817.46
Baker.....	7,488.39	5	7,488.39	{Special, district.....		7,817.46	
Bay.....	4,998.86	2	4,998.86	.....			
Bradford.....	13,316.58	3½	9,983.26	.....			3,333.32
Brevard.....	47,029.73	6	25,839.03	{Special, district 1.....		10,957.34	21,190.70
Calhoun.....	13,650.00	3½	6,650.00	{Special, district 4.....		9,329.86	
Citrus.....	26,698.71	5½	12,555.66	Auto tax.....		903.50	7,000.00
Clay.....	15,858.24	4½	10,031.94	{Labor tax.....		4,000.00	
Columbia.....	13,826.71	4	12,130.35	{Convicts.....		3,000.00	
Dade.....	68,500.00	7½	68,500.00	Special, districts 1-5.....			14,143.05
De Soto.....	59,847.22	5½	47,047.22	Special, district.....	5		5,826.30
Duval.....	150,000.00			Statute labor tax.....			1,696.36
Escambia.....	18,438.60	1½	18,438.60	Special, district 5.....			12,800.00
Franklin.....	4,476.08	2	2,728.60	General fund.....			150,000.00
Gadsden.....	17,646.44	5	11,646.44	Fines.....			1,747.48
Hamilton.....	9,339.66	2	4,937.58	Statute labor tax.....			6,000.00
Hernando.....	6,400.00	2½	3,851.90	.....			4,402.08
Hillsboro.....	9,392.27	2	4,173.89	{Other revenues.....		2,288.10	2,548.10
Holmes.....	6,995.06	4	6,755.06	{Auto tax.....		260.00	
Jackson.....	5,984.55	1½	5,984.55	Special road tax.....	2½		5,217.38
Jefferson.....	12,774.75	3	7,302.68	Auto license.....			240.00
Lafayette.....	11,568.75	4	11,568.75	.....			
Lake.....	21,430.85	4	18,930.85	Other sources.....			5,472.07
Lee.....	45,867.68	6	42,867.68	Convict labor.....			2,500.00
Leon.....	22,899.92	7	21,418.00	Road district No. 1.....			3,000.00
Levy.....	11,618.29	1	3,246.60	{Auto license.....		371.00	1,482.92
Liberty.....	3,383.36	2½	3,383.36	{Special tax.....		64.00	
Madison.....	15,311.40	4	15,311.40	Sale of tolls.....		309.00	
Manatee.....	28,950.25	5	26,925.25	Road districts 1-5.....			8,371.69
Marion.....	36,553.49	4½	26,953.62	Auto license.....			2,025.00
Monroe.....	634.00	5½	634.00	Convict labor.....		1,636.14	9,599.87
Nassau.....	10,070.49	1	3,270.49	Labor tax.....		6,372.73	
Orange.....	34,786.32	5	32,700.00	Auto license.....		1,591.00	
Osceola.....	26,304.55	5	26,304.55	.....			
Palm Beach.....	165,446.65	1	65,867.25	Convict labor.....			6,800.00
Pasco.....	33,900.00	3	8,800.00	Other sources.....			2,086.32
				Special road district.....	2		99,579.40
				{Convict labor.....		1,700.00	25,100.00
				Road districts 1, 2, 3.....		23,200.00	
				Auto receipts.....		200.00	

¹ Includes \$737.92 received from hire of convicts.

FLORIDA—Continued.

TABLE 10.—County revenue applied to roads and bridges in 1914—Continued.

County.	Total revenue applied to roads and bridges.	General county tax.		Receipts from other sources.			
		Rate, mills per \$1.	Receipts.	Source.	Rate.	Receipts.	Total receipts.
Pinellas.....	\$44,330.00	5	\$35,830.00	Auto registration..	<i>Mills.</i>		\$8,500.00
Polk.....	93,932.16	6½	93,932.16				
Putnam.....	23,831.70	4½	23,831.70				
St. Johns.....	38,705.22	4	16,020.00				22,685.22
St. Lucie.....	60,354.03	5½	35,325.08	Special road district.			25,028.95
Santa Rosa.....	40,419.26	5	22,300.00	Other sources.....			18,119.26
Seminole.....	47,270.09	7	26,747.00	Special road district.			20,523.09
Sumter.....	10,480.40	5	9,480.40	Convict labor.....			1,000.00
Suwanee.....	23,610.74	3	7,622.67	{Special warrants.....		\$15,673.57	15,988.07
Taylor.....	9,757.06	3	9,757.06	{Convict labor.....		314.50	
Volusia.....	65,711.53	6	57,709.53	Auto licenses.....			8,002.00
Wakulla.....	2,385.50	3	2,385.50				
Walton.....	29,484.86	5	21,620.39	{Auto tax.....		500.00	7,864.47
Washington.....	10,449.90	2½	4,762.50	{Special road district.		7,364.47	
				Other sources.....		5,687.40	5,687.40
Total.....	1,515,203.32		969,825.36				545,377.96

GEORGIA.

TABLE 11.—County revenue applied to roads and bridges in 1914.

County.	Total revenue applied to roads and bridges.	County road and bridge tax.		Amounts obtained from automobile licenses.	Amounts obtained from commutation tax.	Statute labor tax.			
		Rate, mills per \$1.	Amount obtained.			Number of men who worked roads.	Number of days worked.	Average wage of hired help.	Cash value of labor performed.
Appling.....	\$12,943.00		\$10,000.00	\$943.00	\$2,000.00				
Baker.....	20,472.00		16,000.00	472.00	4,000.00				
Baldwin.....	15,896.00		10,000.00	396.00	5,500.00				
Banks.....	12,675.00	4	7,000.00	525.00	5,150.00				
Bartow.....	25,823.00		19,000.00	1,123.00	5,700.00				
Ben Hill.....	14,827.00	5	14,478.00	349.00					
Berrien.....	32,804.00	{ 1 1.5 2 2	10,983.00	1,177.00	6,000.00				
			14,644.00						
Bibb.....	51,871.00	1.56	51,402.00	469.00					
Bleckley.....	7,356.00	3.3	5,000.00	356.00	2,000.00				
Brooks.....	21,373.00	2	13,750.00	887.00	6,736.00				
Bryan.....	11,334.00		8,000.00	334.00	3,000.00				
Bulloch.....	33,210.00	3	24,000.00	1,210.00	8,000.00				
Burke.....	32,932.00		20,000.00	932.00	12,000.00				
Butts.....	12,048.00	4	9,459.00	589.00	2,000.00				
Calhoun.....	31,442.00		23,999.00	443.00	7,000.00				
Camden.....	9,553.00	2.5	6,265.00	196.00	1,997.00	146	5	\$1.50	\$1,095.00
Campbell.....	22,778.00	5.8	17,400.00	578.00	4,800.00				
Candler.....	2,500.00				2,500.00				
Carroll.....	22,959.00	2	14,654.00	1,525.00	6,500.00	40	7	1.00	280.00
Catoosa.....	9,134.00		5,827.00	307.00		600	4	1.25	3,000.00
Charlton.....	5,920.00	2	4,000.00	120.00	1,500.00	100	3	1.00	300.00
Chatham.....	50,176.00		50,000.00	176.00					
Chattahoochee.....	9,498.00		6,000.00	323.00	3,175.00				
Chattooga.....	13,612.00	2	7,000.00	612.00	3,000.00	500	4	1.50	3,000.00
Cherokee.....	24,362.00	4	15,383.00	979.00	8,000.00				
Clarke.....	36,082.00	5	32,764.00	318.00	3,000.00				
Clay.....	11,531.00	4	6,702.00	429.00	4,400.00				
Clayton.....	12,725.00	4	8,712.00	463.00	3,550.00				

¹ Bridges.² Roads.

GEORGIA—Continued.

TABLE 11.—County revenue applied to roads and bridges in 1914—Continued.

County.	Total revenue applied to roads and bridges.	County road and bridge tax.		Amounts obtained from automobile licenses.	Amounts obtained from commutation tax.	Statute labor tax.			
		Rate, mills per \$1.	Amount obtained.			Number of men who worked roads.	Number of days worked.	Average wage of hired help.	Cash value of labor performed.
Clinch.....	\$6,527.00	2 3	\$5,256.00	\$271.00	\$1,000.00				
Cobb.....	43,751.00	4	36,018.00	1,483.00	6,250.00				
Coffee.....	15,247.00	2	10,340.00	907.00	4,000.00		4	\$1.00	
Colquitt.....	45,467.75		36,838.00	847.00	7,689.00	15	5	1.25	\$93.75
Columbia.....	2,378.00			378.00	2,000.00			1.00	
Coweta.....	53,622.00	4	42,697.00	1,179.00	8,996.00	125	8	.75	750.00
Crawford.....	19,476.00		12,500.00	476.00	3,500.00	375	8	1.00	3,000.00
Crisp.....	23,534.00	4	20,000.00	534.00	3,000.00				
Dade.....	3,382.00	1 5	3,253.00	129.00				1.00	
Dawson.....	13,565.00	2 5	2,374.00	191.00	3,000.00	1,000	8	1.00	8,000.00
Decatur.....	38,654.00	4	30,000.00	954.00	7,500.00	40	5	1.00	200.00
Dekalb.....	45,899.00	4	40,000.00	749.00	5,000.00	30	5	1.00	150.00
Dodge.....	28,905.00	4	23,006.00	899.00	5,000.00		6		
Dooley.....	25,066.00		12,170.00	896.00	12,000.00				
Dougherty.....	25,485.00		21,147.00	338.00	4,000.00				
Douglas.....	13,383.00	3 5	7,700.00	583.00	3,500.00	200	8	1.00	1,600.00
Early.....	35,701.00	5	25,000.00	701.00	10,000.00				
Echols.....	933.00			133.00	800.00				
Effingham.....	18,739.00	4	15,000.00	489.00	1,000.00	500	5	.90	2,250.00
Elbert.....	7,485.00			985.00	6,500.00				
Emanuel.....	23,712.00		13,500.00	1,212.00	9,000.00				
Fannin.....						(¹)			
Fayette.....	11,136.00	4	6,478.00	465.00	4,193.00			1.00	
Floyd.....	77,596.00	3 2	65,000.00	996.00	11,600.00				
Forsyth.....	9,181.00		8,500.00	681.00					
Franklin.....	28,194.00		19,000.00	994.00	7,000.00	300	4	1.00	1,200.00
Fulton.....	424,254.00	3 2	423,800.00	454.00					
Gilmer.....	2,174.00		2,000.00	174.00					
Glascock.....	4,537.00	4	2,677.00	260.00	1,600.00				
Glynn.....	10,652.00	1 3	8,753.00	99.00	1,800.00				
Gordon.....	16,365.00	2	8,500.00	865.00	7,000.00				
Grady.....	24,994.00	4	14,000.00	894.00	10,000.00	10	10	1.00	100.00
Greene.....	30,012.00		23,030.00	758.00	6,224.00				
Gwinnett.....	51,375.00		35,000.00	1,375.00	15,000.00				
Habersham.....	10,783.00		4,000.00	383.00	6,400.00				
Hall.....	64,388.00		29,720.00	968.00	13,700.00	2,500	8	1.00	20,000.00
Hancock.....	13,607.00		7,000.00	607.00	6,000.00				
Haralson.....	8,712.00		5,600.00	712.00	2,400.00				
Harris.....	21,619.00	2 5	15,500.00	1,119.00	5,000.00				
Hart.....	15,059.00	4 5	9,356.00	703.00	5,000.00				
Heard.....	7,916.00		1,200.00	716.00	6,000.00				
Henry.....	42,929.00	² 3	13,500.00	929.00	6,000.00	2,000	6	.75	9,000.00
Houston.....	23,321.00	4	18,396.00	925.00	4,000.00				
Irwin.....	10,783.00		5,585.00	398.00	4,800.00				
Jackson.....	27,283.00	7 5	20,000.00	1,283.00	6,000.00				
Jasper.....	24,592.00	4	16,905.00	687.00	7,000.00				
Jeff Davis.....	6,030.00	2	4,500.00	280.00	1,250.00				
Jefferson.....	17,969.00	2	8,097.00	1,103.00	8,769.00				
Jenkins.....	12,913.00	4	8,250.00	463.00	4,200.00				
Johnson.....	9,291.00	10	4,725.00	528.00	4,038.00				
Jones.....	10,096.00		5,000.00	596.00	4,500.00				
Laurens.....	57,832.00	6 9	48,355.00	1,477.00	8,000.00				
Lee.....	18,905.00		15,000.00	405.00	3,500.00				
Liberty.....	19,217.00	6	17,543.00	474.00	1,200.00				
Lincoln.....	10,315.00	4	4,777.00	409.00	5,129.00				
Lowndes.....	22,019.00		18,500.00	1,019.00	2,500.00				
Lumpkin.....	8,015.00	2 5	3,337.00	278.00	4,400.00				
McDuffie.....	10,180.00	4	8,000.00	380.00	1,800.00				
McIntosh.....	8,260.00	4	5,560.00		2,700.00				
Macon.....	29,612.00	7 6	24,830.00	552.00	4,230.00				
Madison.....	13,293.00		3,000.00	863.00	9,430.00				
Marion.....	7,227.00		3,000.00	627.00	3,600.00				
Meriwether.....	63,763.00	9	55,000.00	1,163.00	7,000.00	100	8	.75	600.00
Miller.....	8,652.00	2	5,200.00	452.00	3,000.00				
Milton.....	16,177.00		11,000.00	427.00	4,750.00				
Mitchell.....	90,876.00		78,000.00	876.00	12,000.00				
Monroe.....	24,680.00		17,719.00	961.00	6,000.00				

¹ Men work roads.² Bridges.³ Roads.

GEORGIA—Continued.

TABLE 11.—County revenue applied to roads and bridges in 1914—Continued.

County.	Total revenue applied to roads and bridges.	County road and bridge tax.		Amounts obtained from automobile licenses.	Amounts obtained from commutation tax.	Statute labor tax.			
		Rate, mills per \$1.	Amount obtained.			Number of men who worked roads.	Number of days worked.	Average wage of hired help.	Cash value of labor performed.
Montgomery	\$46,313.00	1.65	\$43,514.00	\$549.00	\$2,250.00				
Morgan	30,665.00	2.75	20,000.00	665.00	10,000.00				
Murray	15,630.00	5	10,148.00	482.00	5,000.00				
Muscogee	103,437.00	4	98,994.00	443.00	4,000.00				
Newton	23,412.00	¹ 1 ² 4	3,149.00 12,596.00	667.00	7,000.00				
Oconee	8,922.00	2	3,975.00	447.00	4,500.00				
Oglethorpe	23,103.00		15,000.00	903.00	7,200.00				
Paulding	19,234.00		13,500.00	734.00	5,000.00				
Pickens	11,981.00		5,698.00	432.00	5,851.00				
Pierce	14,404.00	3	11,877.00	527.00	2,000.00				
Pike	11,783.00		5,000.00	783.00	6,000.00				
Polk	32,669.00	3.5	25,000.00	669.00	7,000.00				
Pulaski	22,622.00	6.25	20,199.00	423.00	2,000.00				
Putnam	16,561.00	3	9,237.00	483.00	6,841.00				
Quitman	6,698.00		6,500.00	198.00					
Rabun	9,239.00	4	7,077.00	162.00	2,000.00				
Randolph	23,873.00	4	15,200.00	923.00	7,750.00				
Richmond	64,242.00		63,790.00	452.00					
Rockdale	15,778.00		12,000.00	293.00	3,485.00				
Schley	12,269.00	8.5	9,000.00	269.00	3,000.00				
Screven	13,417.00	2	6,558.00	859.00	6,000.00		10	\$1.00	
Spalding	17,003.00	2.1	12,266.00	487.00	4,250.00				
Stephens	14,227.00	4	10,000.00	387.00	3,000.00	280	3	1.00	\$840.00
Stewart	18,556.00	4	12,000.00	556.00	6,000.00			1.00	
Sumter	49,379.00		42,000.00	879.00	6,500.00				
Talbot	14,535.00	4	8,613.00	707.00	5,215.00				
Taliaferro	6,726.00		4,000.00	280.00	2,446.00				
Tattnall	19,817.00	2	10,858.00	959.00	8,000.00				
Taylor	33,766.00	4	28,000.00	516.00	5,250.00				
Telfair	19,533.00	4	15,517.00	516.00	3,500.00				
Terrell	15,296.00		7,000.00	796.00	7,500.00				
Thomas	38,933.00	7	27,975.00	1,114.00	9,844.00			1.00	
Tift	10,228.50	2	7,539.00	552.00	1,800.00	45	6	1.25	337.50
Toombs	26,808.00	¹ 1.5 ² 5	5,267.00 17,542.00	499.00	3,500.00		6		
Towns	107.00			107.00		(3)			
Troup	53,899.00	¹ 2 ² 4	15,000.00 32,000.00	899.00	6,000.00				
Turner	19,071.00	4	11,000.00	481.00	7,590.00				
Twiggs	12,903.00		10,000.00	503.00	2,400.00				
Union	200.00			200.00		(3)			
Upson	19,655.00		11,500.00	619.00	7,536.00				
Walker	19,817.00		12,000.00	917.00	6,900.00				
Walton	36,483.00	6.5	30,000.00	983.00	5,500.00				
Ware	53,431.00	6.5	50,250.00	554.00	2,627.00				
Warren	23,158.00	4.5	18,000.00	449.00	4,709.00				
Washington	24,504.00	3	15,000.00	1,204.00	8,300.00				
Wayne	18,265.00	3	15,500.00	265.00	2,500.00				
Webster	6,553.00	2	2,199.00	354.00	4,000.00				
Wheeler	343.00			343.00					(4)
White	3,638.00		1,300.00	353.00	1,985.00				
Whitfield	25,218.00	4	20,000.00	718.00	4,500.00				
Wilcox	15,054.00		8,400.00	554.00	2,100.00	500	4	2.00	4,000.00
Wilkes	25,627.00		13,000.00	627.00	12,000.00				
Wilkinson	15,645.00		10,000.00	645.00	5,000.00				
Worth	18,010.00		10,000.00	1,010.00	7,000.00				
Total	3,688,172.25		2,827,352.00	92,739.00	708,285.00	9,406			59,796.25

¹ Bridges.² Roads.³ Men work roads.⁴ New law.

KENTUCKY.

TABLE 12.—County revenue applied to roads and bridges, 1914.

County.	Total revenue applied to roads and bridges.	Property tax.		Statute labor tax.				Other revenues applied to roads.
		Rate in cents per \$100.	Receipts from property tax.	Number of men worked out labor, 1914.	Average number of days worked per man.	Average daily wage for hired help.	Cash value of statute labor tax.	
Adair.....	\$23,389	0.20	\$5,389	3,000	6	\$1.00	\$18,000	
Allen.....	12,461	.20	12,461					
Anderson.....	20,000		20,000					
Ballard.....	19,668	.25	19,668					
Barren.....	21,093	.10	21,093					
Bath.....	13,000	.25	13,000					
Bell.....	36,076	.23	22,476	1,600	6	1.00	9,600	¹ \$4,000
Boone.....	35,508	.40	24,858					² 10,650
Bourbon.....	50,624	.25	44,624					² 6,000
Boyd.....	25,410	.20	25,410					
Boyle.....	28,250	.25	27,000	200	5	1.25	1,250	
Bracken.....	14,142	.16	14,142					
Breathitt.....	400			200	2	1.00	400	
Breckinridge.....	23,669	.25	13,669	2,500	4	1.00	10,000	
Bullitt.....	11,233	.25	11,233					
Butler.....	9,135	.20	5,535	1,200	3	1.00	3,600	
Caldwell.....	11,535	.25	11,535					
Calloway.....	10,664	.22	10,664					
Campbell.....	64,076	.25	64,076					
Carlisle.....	7,929	.25	7,929					
Carroll.....	11,816	.25	11,816					
Carter.....	15,000	.23	10,000	1,000	4	1.25	5,000	
Casey.....	8,795	.25	8,795					
Christian.....	46,827	.235	37,067					¹ 2,000
Clark.....	38,963	.25	38,963					² 7,760
Clay.....								
Clinton.....	3,520	.25	3,520					
Crittenden.....								
Cumberland.....	1,965	.05	1,965					
Daviess.....	94,234	.35	92,134					
Edmonson.....	19,740	.10	6,740	1,500	6	1.00	9,000	³ 2,100
Elliott.....	6,317	.25	2,717	600	6	1.00	3,600	³ 4,000
Estill.....	4,000	.30	4,000					
Fayette.....	90,205	.20	90,205					
Fleming.....	15,769	.25	15,769					
Floyd.....	7,000	.30	7,000					
Franklin.....	26,000	.25	26,000					
Fulton.....	13,474	.25	13,474					
Gallatin.....	6,736	.25	6,736					
Garrard.....	26,453	.25	26,453					
Grant.....	27,613	.25	27,613					
Graves.....	42,684		42,684					
Grayson.....	9,515	.25	9,515					
Green.....	15,600	.15		2,600	6	1.00	15,600	
Greenup.....	24,834	.20	24,834					
Hancock.....	17,700	.25	6,000	1,560	6	1.25	11,700	
Hardin.....	22,000	.25	22,000					
Harlan.....								
Harrison.....	21,433	.25	21,433					
Hart.....	17,336	.25	17,336					
Henderson.....	46,000	.25	40,000					⁴ 6,000
Henry.....	17,701	.25	17,701					
Hickman.....	7,446	.20	7,446					
Hopkins.....	29,273	.25	29,273					
Jackson.....	12,800	.05	800	2,000	6	1.00	12,000	
Jefferson.....	225,591	.10	225,591					
Jessamine.....	24,704	.25	24,704					
Johnson.....	4,000	.10	4,000					
Kenton.....	62,660	.25	62,660					
Knott.....	1,174		1,174					
Knox.....	8,000	.20	8,000					
Larue.....	9,180	.20	9,180					
Laurel.....	8,000	.25	8,000					
Lawrence.....	9,122	.38	9,122					
Lee.....	5,002			667	6	1.25	5,002	
Leslie.....	2,222	.10	2,222					
Letcher.....	13,619	.25	13,619					
Lewis.....	19,336	.17	9,961	2,500	3	1.25	9,375	
Lincoln.....	29,750	.25	23,750	2,000	3	1.00	6,000	

¹ Poll tax.² Franchise and poll tax.³ Private subscriptions.⁴ Special tax.

KENTUCKY—Continued.

TABLE 12.—County revenue applied to roads and bridges, 1914—Continued.

County.	Total revenue applied to roads and bridges.	Property tax.		Statute labor tax.				Other revenues applied to roads.
		Rate in cents per \$100.	Receipts from property tax.	Number of men worked out labor, 1914.	Average number of days worked per man.	Average daily wage for hired help.	Cash value of statute labor tax.	
Livingston.....	\$12,100	0.20	\$6,100	1,000	6	\$1.00	\$6,000	.....
Logan.....	28,952	.25	28,952					.....
Lyon.....	7,972		5,972	1,000	2	1.00	2,000	.....
McCracken.....	37,418	.20	37,418					.....
McCreary.....	3,742	.10	3,742					.....
McLean.....	17,054	.225	6,344	2,400	3	1.25	9,000	¹ \$1,710
Madison.....	34,421	.25	34,421					.....
Magoffin.....	15,750		3,750	2,000	6	1.00	12,000	.....
Marion.....	16,000	.25	16,000					.....
Marshall.....	15,000	.25	15,000					.....
Martin.....	7,975		775	800	6	1.50	7,200	.....
Mason.....	37,831	.25	37,831					.....
Meade.....	7,769	.25	7,769					.....
Menifee.....	2,725	.20	2,725					.....
Mercer.....	26,511	.25	24,111	1,200	2	1.00	2,400	.....
Metcalfe.....	4,000	.25	4,000					.....
Monroe.....	10,011		8,311					² 1,700
Montgomery.....	25,973	.25	25,973					.....
Morgan.....		.25						.....
Muhlenberg.....	18,708	.25	18,208				500	.....
Nelson.....	41,773	.35	39,773				1,000	² 1,000
Nicholas.....	17,433	.25	14,806					² 2,627
Ohio.....	23,350	.25	23,000					² 350
Oldham.....	16,000	.25	16,000					.....
Owen.....	22,545	.30	13,545	1,000	6	1.50	9,000	.....
Owsley.....								.....
Pendleton.....	14,769	.25	14,769					.....
Perry.....								.....
Pike.....	8,000	.10	8,000					.....
Powell.....	2,500	.15	2,500					.....
Pulaski.....	20,500	.25	20,500					.....
Robertson.....	6,250	.25	6,250					.....
Rockcastle.....	6,283	.35	6,283					.....
Rowan.....	2,000		2,000					.....
Russell.....	4,159	.20	2,959				1,200	.....
Scott.....	24,352	.25	24,352					.....
Shelby.....	38,907	.25	38,907					.....
Simpson.....	22,950		18,000	500	3	1.50	2,250	² 2,700
Spencer.....	4,500		4,500					.....
Taylor.....	6,820	.15	4,720	700	4	.75	2,100	.....
Todd.....	17,893	.30	14,893					² 3,000
Trigg.....	8,204		8,204					.....
Trimble.....	9,750	.35	6,000	500	6	1.25	3,750	.....
Union.....	28,798	.25	28,798					.....
Warren.....	39,462	.25	39,462					.....
Washington.....	12,500	.25	12,500					.....
Wayne.....	28,900	.25	6,400	3,000	6	1.25	22,500	.....
Webster.....	16,585	.22	16,585					.....
Whitley.....	17,654	.25	17,654					.....
Wolfe.....								.....
Woodford.....	35,501	.25	35,501					.....
Total.....	2,437,621		2,180,997				201,027	55,597

¹ Poll tax.² Private subscription.

LOUISIANA.

TABLE 13.—Revenue applied to roads and bridges in 1914.

Parish. ¹	Total revenue applied to roads and bridges.	General road tax for fiscal year ended 1914.			Other revenues applied to roads.				Statute labor tax.			
		Rate, mills per \$1.		Amounts obtained.	Source.	Rate.	Amounts obtained.	Total.	Number men who worked out tax.	Number of days worked per man.	Daily wage for hired help.	Cash value of labor tax.
		Parish.	Ward.									
Acadia.....	\$38,000.00			\$38,000.00	Special ward tax.....	3 to 5 mills.	\$5,823.00	\$5,823.00				
Allen.....	5,823.00				Police jury.....	3 mills	10,670.59	10,670.59				
Ascension.....	62,000.00			62,000.00	Capitation tax.....	\$1.....	6,500.00	6,500.00				
Assumption.....	10,670.59				Special ward tax.....	5 mills	33,009.80	33,009.80				
Avozelles.....	11,500.00		1	5,000.00	Capitation tax.....	\$1.....	3,800.00	3,800.00				
Beauregard.....	33,009.80				Vehicle and capitation tax.....		10,470.00	10,470.00				
Bienville ²	7,457.00		1	3,657.00	Automobile licenses.....	3 mills	1,200.00	31,200.00				
Bossier.....	10,470.00				Special ward tax.....		30,000.00					
Caddo.....					Capitation tax.....		940.00	1,040.00				
Calcasieu.....	31,200.00				Vehicle tax.....		106.41	480.04				
Caldwell.....	8,891.31		1.5	7,226.31	Capitation tax.....		373.63					
Cameron.....	7,269.00			6,144.00	General fund.....	2 mills	3,000.00	3,000.00				
Catahoula.....	2,672.73				Special tax.....		12,000.00	12,000.00				
Clabornie.....	4,160.00			4,160.00	General fund.....		11,000.00	11,000.00				
Concordia.....	3,400.00				Automobile licenses.....		300.00	4,800.00				
De Soto.....	12,000.00				Capitation tax.....		2,000.00					
East Baton Rouge.....	11,000.00				Vehicle tax.....		2,500.00					
East Carroll.....	9,300.00			4,500.00	Special ward tax.....		20,000.00	20,000.00				
East Feliciana.....	7,205.99				Police jury.....		4,000.00	4,000.00				
Evangeline.....	12,649.00											
Franklin.....	15,146.18											
Grant.....	30,000.00											
Iberia.....	4,000.00											
Iberville.....	12,100.00											

¹ Corresponds with county in other States² No road fund.³ One ward.

	12,000.00	2	2-5	12,000.00	Special ward tax (Capitation tax)	\$1.	2,200.00 2,500.00	4,700.00				
St. Tammany.....	12,000.00	2	2-5	12,000.00	Special ward tax (Capitation tax)	\$1.	2,200.00 2,500.00	4,700.00				
Tangipahoa.....	38,041.00	2.25		33,341.00								
Tensas.....	3,500.00			3,500.00								
Terrebonne ¹	13,800.00			13,800.00								
Union ¹	13,800.00			13,800.00								
Vermilion.....	7,500.00			7,500.00								
Vernon.....	60,502.21	2		20,502.21					2,000	12	1.25	
Washington.....	8,000.00			8,000.00						10	2.00	40,000.00
Webster.....	16,677.78			12,495.61								
West Baton Rouge.....	6,000.00		3-5	6,000.00		(⁶)	{ 900.00 2,105.00 }	3,432.17	200	3	1.25	750.00
West Carroll.....	1,700.00			1,700.00								
West Feliciana.....	1,500.00			1,500.00								
Winn ¹	13,800.00			13,800.00								
Total.....	829,677.70			533,294.10				250,648.60				45,735.00
Expended by State on highways	461,505.73											
Reported as expended from												
bond issues on county roads	486,388.69											
and bridges.....												
Grand total.....	1,777,572.12											

¹ No reports were received from these parishes, but it was found that the average for those parishes reporting is \$13,800.

² No road fund.

³ All within the city limits of New Orleans.

⁴ Convicts.

⁵ Auto fees \$427.17.

MARYLAND.

TABLE 14.—Revenue applied to roads and bridges in 1914.

County.	Total revenue applied to roads and bridges.	General county road tax.		Other revenue applied to roads and bridges.	
		Rate, per \$100.	Amount obtained.	Source.	Amount obtained.
Allegany.....	\$79,833.51			General levy, roads and bridges and State-aid roads.	\$65,000.00
Anne Arundel.....	96,570.90	\$0.35-\$0.79	\$94,631.10	Special appropriation.....	10,000.00
Baltimore.....	559,175.38	.40	551,320.80	Motor license and miscellaneous.	4,833.51
Calvert.....	40,800.00			Special district levies.....	1,939.80
Caroline.....	40,000.00			Donations, auto tax, etc.....	7,854.58
Carroll.....	205,250.00	.68	158,000.00	State-road loan.....	40,800.00
Cecil.....	41,000.00			General levy.....	21,000.00
Charles.....	11,000.00			Extra levy.....	19,000.00
Dorchester.....	103,461.80			County assessment.....	22,500.00
Frederick.....	57,162.99			State-aid road.....	24,750.00
Garrett.....	42,992.09		42,992.09	General levy.....	41,000.00
Harford.....	38,500.00			do.....	11,000.00
Howard.....	22,000.00	1.00	21,000.00	Hern bond act, special.....	28,097.55
Kent.....	21,600.00	.20	21,600.00	County levy, roads and bridges	49,892.76
Montgomery.....	64,480.00			State-road loan.....	25,471.49
Prince Georges.....	48,000.00	.22	43,000.00	New roads and bridges levy...	4,437.89
Queen Annes.....	22,500.00	.20	22,500.00	General levy.....	20,000.00
St. Marys.....	5,000.00			Extra, miscellaneous, etc.....	32,725.10
Somerset.....	20,000.00	.20	20,000.00	General levy.....	38,500.00
Talbot.....	22,000.00			County aid.....	1,000.00
Washington.....	56,999.00	.15½	56,000.00	Special tax.....	35,480.00
Wicomico.....	250,000.00			Special levy, roads and bridges	29,000.00
Worcester.....	16,000.00	.16	16,000.00	Portion of liquor license.....	5,000.00
Total.....	1,863,326.67		1,047,043.99	General levy.....	5,000.00
Approximate amount obtained from State appropriations and State bond issues and applied to State and State-aid roads.....	3,713,279.00			General levy.....	22,000.00
Contributions by counties spent under State supervision.....	309,504.00			State-road loan.....	100,600.00
Expended from county-bond issues during 1914.....	114,542.36			Special appropriation.....	149,400.00
Grand total.....	6,000,652.03				

¹ District.

MISSISSIPPI.

TABLE 15.—County revenue applied to roads and bridges during 1914.

County.	Total revenue applied to roads and bridges.	General county and beat road tax.			Other revenues applied to roads and bridges.		Statute labor tax.			
		County rate, mills per \$1.	Beat rate, mills per \$1.	Amount obtained.	Auto-mobile tax.	Per capita tax.	Number of men who worked.	Number of days worked.	Average daily wage for hired help.	Cash value of labor tax.
Adams.....	\$4,975.44				\$880.27	\$4,095.17				
Alcorn.....	7,950.00	1½		\$6,700.00	1,250.00					
Amite.....										
Attala.....	18,573.35	3	4	18,573.35						
Benton.....	5,200.00	2		3,400.00		1,800.00				
Bolivar.....	97,253.00	5		163,787.00	2,500.00	30,966.00				
Calhoun.....										
Carroll.....	36,757.30	7		26,195.00	608.30	9,954.00				
Chickasaw.....	14,928.43	1	1	7,162.18	560.32	7,205.93				
Choctaw.....	10,624.09	3		10,624.09						
Claitborne.....	7,000.00	1		4,000.00		3,000.00				
Clay.....	21,810.00			21,810.00						
Clarke.....										
Coahoma.....	73,656.22	9		73,656.22						
Copiah.....		3	6							
Covington.....	5,512.57	1		3,015.89	990.06	1,356.62	10	10	\$1.50	\$150.00
De Soto.....	28,537.33	3	1	18,398.92		10,138.41				
Forrest.....	13,083.47		2½	9,213.18	1,232.96	2,637.33				
Franklin.....	9,123.25			2,160.10		6,963.15				
George.....										
Greene.....	11,267.32			28,278.75		2,988.57				
Grenada.....	19,579.00	3		12,382.00	900.00	6,297.00				
Hancock.....	18,303.74	4		16,553.74		1,750.00				
Harrison.....	49,000.00	2		30,000.00	1,500.00	10,000.00	1,000	5	1.50	7,500.00
Hinds.....	40,935.00	2½		27,285.00	4,000.00	9,650.00				
Holmes.....	40,813.00	2½	8	22,430.00	2,000.00	16,383.00				
Issaquera.....	3,678.93			3,378.93			150	2	1.00	300.00
Itawamba.....	18,850.00	7		3,800.00			2,150	7	1.00	15,050.00
Jackson.....	2,048.13	3		1,748.13			30	8	1.25	300.00
Jasper.....	1,820.00			1,500.00	320.00					
Jefferson.....	14,712.75	3		9,212.75		5,500.00				
Jefferson Davis.....	14,090.98	2		38,207.98		5,883.00				
Jones.....	1,079.55			315.00	764.55					
Kemper.....	20,081.00	2		8,528.00		11,553.00				
Lafayette.....	24,000.00			24,000.00						
Lamar.....	18,000.00	3		18,000.00						
Lauderdale.....	29,299.11	1		20,095.11		9,204.00				
Lawrence.....	10,403.61			6,835.66		3,567.95				
Leake.....										
Lee.....										
Leflore.....	91,359.84			79,149.48		12,210.36				
Lincoln.....	19,008.05	1½		11,055.05		7,953.00				
Lowndes.....	10,642.00	3		10,642.00						
Madison.....	10,500.00	3		10,500.00						
Marion.....	13,000.00	1½		13,000.00						
Marshall.....	23,686.00	3		23,686.00						
Monroe.....										
Montgomery.....	20,440.46	3	3	14,309.41	650.00	5,481.00				
Neshoba.....	12,196.00	1½		3,407.00	83.00	8,706.00				
Newton.....	20,033.10	3-2	3-2	11,073.10	350.00	8,610.00				
Noxubee.....	12,721.43		5	10,947.05		1,774.38				
Oktibbeha.....										
Panola.....		2½								
Pearl River.....	25,500.00	3		23,000.00		2,500.00				
Perry.....										
Pike.....	18,933.00	2		16,133.00	2,800.00					
Prentiss.....										
Pontotoc.....	18,101.35	5		18,101.35						
Quitman.....										
Rankin.....	21,338.06		2½-3	16,488.60	109.03	1,540.43	800	4	1.00	3,200.00
Scott.....										
Sharkey.....	6,440.85	2½		5,440.85			250	4	1.00	1,000.00
Smith.....	11,678.57		5	11,678.57						

¹ Includes \$24,952 property tax.² Includes \$3,145.09 property tax.³ Includes \$72 special tax and \$573 from general funds.⁴ Includes \$4,851.52 special tax.⁵ Includes \$7,772.99 from general funds.

MISSISSIPPI—Continued.

TABLE 15.—County revenue applied to roads and bridges during 1914—Continued.

County.	Total revenue applied to roads and bridges.	General county and beat road tax.			Other revenues applied to roads and bridges.		Statute labor tax.			
		County rate, mills per \$1.	Beat rate, mills per \$1.	Amount obtained.	Auto-mobile tax.	Per capita tax.	Number of men who worked.	Number of days worked.	Average daily wage for hired help.	Cash value of labor tax.
Simpson.....										
Sunflower.....										
Tallahatchie.....	\$51,779.00			\$24,482.00	\$2,256.00	\$25,041.00				
Tate.....	20,500.00	3		12,000.00		8,500.00				
Tippah.....	10,137.19	3		10,137.19						
Tishomingo.....	20,893.00	1-2	1½-2	7,725.00	131.00	1,037.00	2,000	6	\$1.00	\$12,000.00
Tunica.....	33,613.18			21,394.01		12,219.17				
Union.....	13,787.40			5,246.17		8,541.23				
Walthall.....	11,000.00			11,000.00						
Warren.....	174,442.11			¹ 166,102.39	3,201.06	5,138.66				
Washington.....	22,797.00				3,000.00	19,797.00				
Wayne.....										
Webster.....										
Wilkinson.....	16,400.26	3		9,728.26		6,672.00				
Winston.....	13,000.00	2		6,000.00		7,000.00				
Yalobusha.....	22,358.59			22,358.59						
Yazoo.....	40,184.00			20,532.00	1,319.00	18,333.00				
Total.....	1,479,417.01			1,086,564.10	31,405.55	321,947.36				39,500.00

¹ Appropriated from general funds.

NORTH CAROLINA.

TABLE 16.—County revenue applied to roads and bridges in 1914.

County.	Total revenue applied to roads and bridges.		Property and poll tax.		Special taxes.	Other revenue applied to roads.			Statute labor tax.			Bridge tax.
	County rate, cents per \$100.	Township rate, cents per \$100.	Total receipts.	Source.		Receipts.	Total receipts.	Number of men worked.	Number of days worked.	Cash value at \$1 per day.		
Alamance.....	16½		\$17,629.98			{Private subscriptions. Auto tax.	{ \$400.00 1,004.00	{ \$1,404.00	2,000	3	\$6,000.00	
Alexander.....	25	75	1,000.00			{Private subscriptions. Auto tax.	{ 131.60 500.00	{ 131.60	1,500	6	9,000.00	
Alleghany.....			5,401.60			{Private subscriptions. Auto tax.	{ 1.60 1,000.00	{ 501.60	700	7	4,900.00	
Anson.....	25-30	75-90	22,183.00			{Private subscriptions. Auto tax.	{ 1,494.40 20.00	{ 1,494.40	2,000	6	12,000.00	
Ashe.....	20		4,500.00			{Private subscriptions. Auto tax.	{ 8.00 856.20	{ 8.00	1,000	8	8,000.00	
Avery.....	20½	10-200	8,256.03			{Private subscriptions. Auto tax.	{ 125.60 500.00	{ 625.60	3,000	4	12,000.00	
Beaufort.....	20½		13,724.73			{Private subscriptions. Auto tax.	{ 100.40 5,000.00	{ 100.40	1,000	6	6,000.00	
Bertie.....	10		6,000.00			{Private subscriptions. Auto tax.	{ 3,495.40 316.20	{ 8,495.40	2,835	4	11,340.00	\$7,000.00
Bladen.....	25	12-36	5,500.00			{Private subscriptions. Auto tax.	{ 500.00 1,100.60	{ 316.20	1,200	6	7,200.00	
Brunswick.....	20	20	52,928.76			{Private subscriptions. Auto tax.	{ 1,800.00 439.40	{ 1,600.60	3,000	6	18,000.00	
Buncombe.....	20	8½	11,059.44			{Private subscriptions. Auto tax.	{ 60.00 127.60	{ 2,239.40	1,000	6	6,000.00	
Burke.....	30		30,480.00			{Private subscriptions. Auto tax.	{ 300.00 312.80	{ 127.60	800	6	4,800.00	
Cabarrus.....			400.00			{Private subscriptions. Auto tax.	{ 2,000.00 1,100.40	{ 2,412.80	1,500	4	6,000.00	
Caldwell.....			5,660.00			{Private subscriptions. Auto tax.	{ 800.00 284.80	{ 3,100.40	3,000	6	18,000.00	
Camden.....	15	4	3,000.00			{Private subscriptions. Auto tax.	{ 105.60 100.00	{ 105.60	600	6	3,600.00	
Carteret.....	10		24,113.65		Dog tax, \$1,800.	{Private subscriptions. Auto tax.	{ 431.80 4.00	{ 531.80	1,400	8	11,200.00	
Caswell.....		20, 30	6,836.76		{Dog tax, \$1,100. Corporation tax, \$1,103.	{Private subscriptions. Auto tax.	{ 852.20	{ 852.20	300	4	1,200.00	
Catawba.....			25,000.00			{Private subscriptions. Auto tax.	{ 105.60 100.00	{ 105.60	600	6	3,600.00	
Chatham.....	10	{ 21½, 55, 35, 105	5,300.00			{Private subscriptions. Auto tax.	{ 431.80 4.00	{ 531.80	1,400	8	11,200.00	
Cherokee.....	10	7½-60	1,109.00			{Private subscriptions. Auto tax.	{ 852.20	{ 852.20	300	4	1,200.00	
Chowan.....	10		23,000.00			{Private subscriptions. Auto tax.	{ 105.60 100.00	{ 105.60	600	6	3,600.00	
Clay.....	25					{Private subscriptions. Auto tax.	{ 100.00 4.00	{ 4.00	300	4	1,200.00	
Cleveland.....						{Private subscriptions. Auto tax.	{ 852.20	{ 852.20	300	4	1,200.00	

Hertford.....	28,149.00	5-30	12,703.00	do.....	446.00	2,500	6	15,000.00
Hoke.....	7,969.20	25, 75	7,500.00	do.....	469.20	500	6	3,000.00
Hyde.....	4,739.29	20, 60	1,553.69	{Federal fund	3,802.88			
Iredell.....	47,301.01	25, 75	36,221.23	{Auto tax.....	1,377.40			5,899.50
Jackson.....	17,134.00	10-55	9,118.00	do.....	16.00	2,000	4	8,000.00
Johnston.....	42,146.24	25	28,874.24	{Private subscriptions.	1,000.00	1,800	6	10,800.00
Jones.....	9,478.79	20, 60	6,608.79	{Auto tax.....	1,475.00	1,000	2	2,000.00
Lee.....	8,951.60	17½, 60	8,655.00	{Auto tax.....	296.60			
Lenoir.....	54,332.12	18	14,257.72	{Private subscriptions.	1,500.00			
Lincoln.....	12,440.20	20, 60	12,000.00	{Auto tax.....	1,044.40			
McDowell.....	34,680.59	10	11,763.39	do.....	449.20			
Macon.....	30,556.08	34	8,200.48	{Private subscriptions.	62.00	1,000	6	6,000.00
Madison.....	19,922.70	30	10,916.70	{Auto tax.....	105.20	1,350	5	6,750.00
Martin.....	20,866.63	16½, 50	9,619.13	{Private subscriptions.	200.00	1,500	4	6,000.00
Mecklenburg.....	143,419.40	30	130,720.00	{Auto tax.....	55.60	1,500	6	9,000.00
Mitchell.....	15,400.00	50	11,000.00	do.....	234.90	1,700	6	10,200.00
Montgomery.....	30,609.89	10	17,927.89	{Special tax	812.60	2,000	4	8,000.00
Moore.....	22,844.20	25, 75	19,000.00	{Auto tax.....	4,699.40	1,100	4	4,400.00
Nash.....	41,452.60	30, 60	40,000.00	{Private subscriptions.	4,200.00	2,000	4	8,000.00
New Hanover.....	77,449.60		75,000.00	{Auto tax.....	2,700.00			
Northampton.....	24,940.80	20	16,308.20	{Private subscriptions.	1,144.20			
Onslow.....	9,350.20	20, 60	4,138.20	do.....	1,452.60	2,700	3	8,100.00
Orange.....	20,171.20	35	18,780.00	do.....	532.60	1,200	4	4,800.00
Pamlico.....	9,324.00	20	3,629.00	{Private subscriptions.	250.00			
Pasquotank.....	10,420.07	13	9,720.27	{Auto tax.....	441.20			
Pender.....	18,582.00	20, 60	7,200.00	{Special tax	175.00	1,360	4	5,440.00
Perquimans.....	13,589.41	35, 105	13,351.41	{Auto tax.....	80.00			
Person.....	12,515.40	25	12,013.00	do.....	699.80	1,400	8	11,200.00
Pitt.....	34,533.40	15, 45	18,500.00	do.....	182.00			
Polk.....	14,100.00	52	10,010.00	{Private subscriptions.	238.00			
Randolph.....	77,649.80	8½	6,500.00	do.....	502.40	2,000	5	10,000.00
Richmond.....	32,002.40	33½, 100	30,333.00	{Auto tax.....	4,000.00	1,000	4	4,000.00
Robeson.....	52,998.98	21	36,521.18	{Private subscriptions.	30,000.00	3,600	4	14,400.00
Rockingham.....	34,973.60	24	28,000.00	{Auto tax.....	500.00			
Rowan.....	54,742.40	35, 105	52,756.00	{Private subscriptions.	1,699.40			
				do.....	1,437.80	3,760	4	15,040.00
				do.....	1,053.60	2,960	2	5,920.00
				do.....	1,986.40			

NORTH CAROLINA—Continued.
TABLE 16.—County revenue applied to roads and bridges in 1914—Continued.

County.	Property and poll tax.		Special taxes.	Other revenue applied to roads.			Statute labor tax.			Bridge tax.
	County rate, cents per \$100.	Township rate, cents per \$100.		Source.	Receipts.	Total receipts.	Number of men worked.	Number of days worked.	Cash value at \$1 per day.	
Rutherford.....	15, 200			{Private subscriptions. Auto tax.	\$200. 00 703. 20	\$903. 20				.....
Sampson.....	12			{Private subscriptions. Auto tax.	1, 500. 00 4, 493. 60	4, 493. 60	3, 000	6	\$18, 000. 00	.....
Scotland.....	20	30-50		do.	1, 100. 80	1, 100. 80				.....
Stanley.....	10	25, 75		do.	1, 702. 60	1, 702. 60	1, 060	4	4, 240. 00	.....
Stokes.....		30-40, 100		{do. R. R. tax.	216. 80 200. 00	416. 80	2, 000	6	12, 000. 00	.....
Surry.....		20, 60		{Private subscriptions. Auto tax.	600. 00 526. 00	1, 126. 00	2, 000	6	12, 000. 00	.....
Swain.....	10			do.	20. 00	20. 00	1, 500	4	6, 000. 00	.....
Transylvania.....		15-25, 45		{do. Auto tax.	216. 60 128. 40	216. 60	1, 500	4	6, 000. 00	.....
Tyrrell.....		15		{Private subscriptions. Auto tax.	128. 40 200. 00	145. 40	1, 500	6	9, 000. 00	.....
Union.....	25	14, 75		{Private subscriptions. Auto tax.	600. 00 612. 20	812. 20	3, 500	6	21, 000. 00	.....
Vance.....	17, 51			{Private subscriptions. Auto tax.	1, 044. 00 3, 643. 00	1, 644. 00				.....
Wake.....	25	(1)		{Dogg tax. Auto tax.	3, 519. 40 619. 60	7, 162. 40				.....
Warren.....	25	25, 75		do.	398. 40	398. 40	500	6	3, 000. 00	.....
Washington.....	20, 60			do.	51. 60	51. 60	1, 500	4	6, 000. 00	.....
Watauga.....	21 3/4			do.	1, 542. 00	1, 542. 00	2, 800	6	16, 800. 00	.....
Wayne.....		10, 30		{do. Auto tax.	200. 00 149. 40	349. 40	3, 000	10	30, 000. 00	.....
Wilkes.....	10			{Private subscriptions. Auto tax.	150. 40 1, 500. 40	1, 500. 40				.....
Wilson.....	25, 75	30, 90		do.	107. 60	107. 60	1, 500	6	9, 000. 00	.....
Yadkin.....	40			do.	8. 00	8. 00	3, 000	6	18, 000. 00	.....
Yancey.....	15			do.						.....
Total.....			(2)		272, 155. 43	272, 155. 43			610, 130. 00	\$89, 525. 50

¹ Five townships, 10 extra.

² Amounts included with "other revenue applied to roads."

OKLAHOMA.

TABLE 17.—County revenue applied to roads and bridges in 1915.

County.	Total revenue applied to roads and bridges.	General county and township tax.		Other revenues applied to roads.	Statute labor tax.			
		Rate, mills per \$1. ¹	Receipts.		Number of men worked out labor tax last fiscal year.	Average number of days worked per man.	Average daily wage for hired help.	Cash value of statute labor tax.
Adair.....	\$14,550.62	0.10	\$5,120.79	\$429.83	1,800	4	\$1.25	\$9,000
Alfalfa.....	60,943.00	.76	60,143.00	800.00				
Atoka.....	26,923.02	1.50	20,351.37	6,571.65				
Beaver.....	19,941.46	.90	16,757.66	3,183.80				
Beckham.....	26,482.55	1.38	26,296.46	186.09				
Blaine.....	37,725.95	1.25	32,673.16	5,052.79				
Bryan.....	29,116.02	.85	26,716.02	2,400.00				
Caddo.....	70,897.76	1.28	49,523.50	5,374.26	2,000	4	2.00	16,000
Canadian.....	26,406.89	1.10	24,009.51	2,397.38				
Carter.....	19,767.00	.235	13,767.00	6,000.00				
Cherokee.....	24,169.83	1.00	14,144.83	25.00	2,000	4	1.25	10,000
Choctaw.....	19,963.17	.96	18,560.67	1,402.50				
Cimarron.....	323.19		323.19					
Cleveland.....	26,918.77		18,118.77		1,100	4	2.00	8,800
Coal.....	17,802.35	1.20	15,093.75	2,708.60				
Comanche.....	28,654.00	.62	28,304.00	350.00				
Cotton.....	10,738.21	.63	5,338.21		1,200	3	1.50	5,400
Craig.....	17,570.00	.70	11,770.00	1,800.00	1,000	2	2.00	4,000
Creek.....	101,505.64	1.38	85,755.39	15,750.25				
Custer.....	45,690.72	1.37	44,840.72	850.00				
Delaware.....	2,372.00		2,000.00	372.00				
Dewey.....	42,728.49	.47	42,406.24	322.25				
Ellis.....	9,060.81		9,060.81					
Garfield.....	55,019.93	.62	54,519.93	500.00				
Garvin.....	19,809.93	.87	19,809.93					
Grady.....	35,932.54	.82	35,932.54					
Grant.....	35,744.54		29,894.54		1,300	3	1.50	5,850
Greer.....	4,486.84	.30	2,530.00	1,956.84				
Harmon.....	22,822.97	.75	9,687.97	1,135.00	1,500	4	2.00	12,000
Harper.....	17,660.58	1.37	16,077.79	1,582.79				
Haskell.....	15,828.31	.65	15,828.31					
Jackson.....	25,406.00	.80	25,050.00	356.00				
Jefferson.....	10,627.09	.24	10,427.09	200.00				
Johnston.....	28,333.90	.94	17,132.90		2,435	4	1.50	11,201
Kay.....	37,681.04		31,009.54	6,671.50				
Kingfisher.....	29,267.75	.64	27,523.05	1,744.70				
Kiowa.....	27,917.28	.86	27,917.28					
Latimer.....	4,639.00	.20	4,453.00	186.00				
Le Flore.....	18,259.20	.04	17,869.20	390.00				
Lincoln.....	39,000.00	1.56	33,000.00	6,000.00				
Logan.....	43,471.32	.90	41,861.32	1,610.00				
Love.....	7,982.00	.51	7,932.00	50.00				
McClain.....	5,750.00	.43	2,750.00		1,000	2	1.50	3,000
McCurtain.....	11,290.39	.20	9,886.89	1,403.50				
McIntosh.....	7,440.77		4,130.40	3,310.37				
Major.....	24,369.16	1.00	24,169.16	200.00				
Marshall.....	10,446.78	.40	9,946.78	500.00				
Mayes.....	25,372.23	.80	22,125.23	185.00	1,225	2	1.25	3,062
Murray.....	16,312.24	.28	14,121.87	1,065.37	500	1½	1.50	1,125
Muskogee.....	69,660.05	.77	60,255.80	4,154.25	1,750	2	1.50	5,250
Noble.....	33,750.87	.97	29,392.10	4,358.77				
Nowata.....	27,059.58	.65	23,395.58	3,664.00				
Okfuskee.....	21,875.00	.865	21,875.00					
Oklahoma.....	82,699.46	.48	72,929.86	9,769.60				
Okmulgee.....	31,040.05	1.45	24,265.05	6,775.00				
Ottawa.....	18,734.38	.55	15,174.89	3,559.49				
Pawnee.....	25,040.00	1.50	23,540.00	1,500.00				
Payne.....	46,882.40		38,047.21	8,835.19				
Pittsburg.....	17,187.50		16,087.50	500.00	100	4	1.50	600
Pontotoc.....	17,887.10	.58	17,887.10					
Pottawatomie.....	46,894.11	1.02	42,894.11	4,000.00				
Roger Mills.....	12,968.03	1.00	12,968.03					
Rogers.....	27,521.68	0.56	27,221.68	300.00				
Seminole.....	8,960.75		8,960.75					
Sequoyah.....	{ 4,876.50 12,153.49	.30	{ 2,876.50 12,153.49	2,000.00				
Stephens.....	19,657.54	1.08	19,457.54	200.00				

¹ This is the rate for general county road purposes. The township rate varies in different townships, but averages about 1.5 mills per \$1. Where the township rate is not given in the table the receipts derived therefrom are included.

OKLAHOMA—Continued.

TABLE 17.—County revenue applied to roads and bridges in 1915—Continued.

County.	Total revenue applied to roads and bridges.	General county and township tax.		Other revenues applied to roads.	Statute labor tax.			
		Rate, mills per \$1.	Receipts.		Number of men worked out labor tax last fiscal year.	Average number of days worked per man.	Average daily wage for hired help.	Cash value of statute labor tax.
Texas.....	\$18,763.15	0.98	\$18,463.15	\$300.00	.....	.....	.....	.....
Tillman.....	23,475.38	.59	23,475.38	.....	.....	.....	.....	.....
Tulsa.....	107,013.38	.71	98,662.44	8,350.94	.....	.....	.....	.....
Wagoner.....	31,935.18	1.00	30,555.18	1,380.00	.....	.....	.....	.....
Washington.....	78,763.61	1.20	76,447.61	2,316.00	.....	.....	.....	.....
Washita.....	{19,394.89}	1.15	{18,810.89}	584.00	.....	.....	.....	.....
	{19,189.94}		{18,939.94}	250.00	.....	.....	.....	.....
Woodward.....	18,173.54	.80	18,173.54	.....	.....	.....	.....	.....
Total.....	2,102,680.80	.....	1,859,572.09	147,820.71	18,910	.....	.....	\$95,288

SOUTH CAROLINA.

TABLE 18.—County revenue applied to roads and bridges in 1914.

County.	Total revenue applied to roads and bridges.	County road and bridge tax.		Other revenues.		Statute labor tax.			
		Rate, mills per \$1.	Receipts.	Sources.	Amounts obtained.	Number of men who worked.	Number of days worked.	Average daily wage.	Cash value.
Abbeville.....	\$4,280.00	1	\$3,880.00	Township labor tax.....	\$4,558.00	100	4	\$1.00	\$400.00
Aiken.....	\$2,153.00	2	27,000.00	Borrowed from banks.....	20,000.00	150	4	1.00	600.00
Anderson.....	34,013.41	(1)	27,013.41	Commutation tax.....	7,000.00				
Bamberg.....	5,000.00	6.50	5,000.00	Commutation tax.....	5,344.50	1,000	6	1.00	6,000.00
Barnwell.....	21,344.50		16,000.00	Chain gang.....	3,500.00				
Beaufort.....	32,000.00		26,000.00	Commutation tax.....	5,000.00				
Berkeley.....	11,500.00	1	2,500.00	Commutation tax.....		2,000	6	1.00	12,000.00
Calhoun.....	7,500.00	1.75	42,000.00	Commutation tax.....	8,270.00	225	3	1.00	675.00
Charleston.....	54,000.00	4	22,609.68	Commutation tax.....		3,000	5	1.00	15,000.00
Cherokee.....	23,284.08	2	13,361.13	Commutation tax.....					
Chester.....	21,631.13		8,574.46	Commutation tax.....					
Chesterfield.....	23,574.46		5,000.00	Commutation tax.....					
Clarendon.....	5,000.00	3	14,000.00	Commutation tax.....	6,000.00				
Colleton.....	20,000.00	1	10,000.00	do.....	5,200.00	25	6	1.00	150.00
Darlington.....	15,350.00	1	4,094.00	Commutation tax.....	3,472.00				
Dillon.....	4,094.00		12,578.00	do.....	6,000.00				
Dorchester.....	16,350.00	4	18,000.00	Fines.....	1,500.00	800	2	1.00	1,000.00
Edgefield.....	25,600.00		7,000.00	Commutation tax.....	4,000.00				
Fairfield.....	8,500.00	2	17,018.96	Commutation tax.....	10,000.00				
Florence.....	21,018.96		3,500.00	Dispensary sales.....	7,072.00				
Georgetown.....	20,572.00			General tax.....					
Greenville.....	216,515.50		216,515.50						
Greenwood.....	28,000.00		28,000.00						
Hampton.....	28,291.80	5	17,000.00	Convict labor.....	6,570.00				
Horry.....	34,950.00	3	9,750.00	Commutation tax.....	4,721.80				
Jasper.....	37,912.84		37,912.84	do.....	24,000.00				
Kershaw.....	18,772.52	2.5	11,828.52	Special road tax.....	1,200.00				
Lancaster.....	17,722.90		17,722.90	Commutation tax.....	6,944.00				
Laurens.....	27,000.00	3	21,500.00	Commutation tax.....	5,500.00				

1 Appropriation.

2 Estimated on basis of 1-mill tax.

3 Estimated on basis of 3-mill tax.

SOUTH CAROLINA.—Continued.

TABLE 18.—County revenue applied to roads and bridges in 1914—Continued.

County.	Total revenue applied to roads and bridges.	County road and bridge tax.		Other revenues.		Statute labor tax.			
		Rate, mills per \$1.	Receipts.	Sources.	Amounts obtained.	Number of men who worked.	Number of days worked.	Average daily wage.	Cash value.
Lee.....	\$13,260.00	2	\$7,000.00	Commutation tax.....	\$6,260.00	.....	.....	.....	.....
Lexington.....	26,000.00	2	13,000.00	2-mill bridge tax.....	13,000.00	.....	.....	.....	.....
Marion.....	15,000.00	.....	13,500.00	Commutation tax.....	1,500.00	.....	.....	.....	.....
Marlboro.....	28,000.00	5	28,000.00	.....	.....	.....	.....	.....	.....
Newberry.....	15,250.00	1	7,250.00	Commutation tax.....	5,000.00	1,000	4	\$0.75	\$3,000.00
Oconee.....	16,100.00	.....	8,000.00	(Automobile license.....	1,500.00	300	4	1.00	1,200.00
Orangeburg.....	59,000.00	.....	50,000.00	Commutation tax.....	9,000.00	.....	.....	.....	.....
Pickens.....	15,000.00	.....	15,000.00	.....	.....	.....	.....	.....	.....
Richland.....	16,142.63	.....	1 16,142.63	.....	.....	.....	.....	.....	.....
Saluda.....	22,594.73	.....	2 5,094.73	.....	.....	3,500	5	1.00	17,500.00
Spartanburg.....	70,800.00	.....	70,800.00	Commutation tax.....	8,000.00	.....	.....	.....	.....
Sumter.....	25,000.00	.....	17,000.00	.....	.....	.....	.....	.....	.....
Union.....	15,000.00	.....	15,000.00	Commutation tax.....	9,000.00	.....	.....	.....	.....
Williamsburg.....	19,122.84	2	10,122.84	Commutation tax.....	10,000.00	.....	.....	.....	.....
York.....	28,273.47	2	18,273.47	Bridge tax.....	.....	.....	.....	.....	.....
Total.....	990,480.37	.....	717,843.07	.....	214,512.30	.....	.....	.....	58,125.00

¹ Estimated on basis of one-fourth of total receipts for all purposes.² Estimated on basis of 2-mill tax.

TENNESSEE.

TABLE 19.—County revenue applied to roads and bridges in 1914.¹

County.	Total revenue applied to roads and bridges.	General county tax.			Other revenues applied to roads and bridges.				Statute labor tax.		
		Rate, cents per \$100.	Cash receipts.	Cash from labor tax.	Source.	Rate, cents per \$100.	Amounts obtained.	Number of men who worked.	Average number of days worked.	Average wages for hired help.	Cash value of labor tax. ²
Anderson.....	\$5,537.13	20	\$5,037.18	.....	.....	.....	.....	100	5	\$1.00	\$500.00
Bedford.....	5,640.32	10	5,640.32	.....	.....	.....	.....	.....	.....	.....	.....
Benton.....	1,476.03	10	1,476.03	.....	.....	.....	.....	.....	.....	.....	.....
Bledsoe.....	1,394.16	12	1,394.16	.....	.....	.....	.....	.....	.....	.....	.....
Blount.....	7,578.02	20	7,578.02	.....	.....	.....	.....	.....	.....	.....	.....
Bradley.....	1,559.17	5	1,559.17	.....	.....	.....	.....	.....	.....	.....	.....
Campbell.....	13,155.57	15	6,405.57	.....	.....	.....	.....	1,800	3	1.25	6,750.00
Cannon.....	2,069.15	10	2,069.15	.....	.....	.....	.....	.....	.....	.....	.....
Carter.....	3,956.00	10	3,956.00	.....	.....	.....	.....	.....	.....	.....	.....
Chatham.....	11,325.00	10	2,730.00	.....	Extra levy.....	15	\$4,095.00	1,200	5	.75	4,500.00
Chester.....	13,601.38	10	1,175.69	.....	Bridge tax.....	10	1,175.69	1,500	5	1.50	11,250.00
Chickasaw.....	7,027.71	10	2,376.97	.....	do.....	20	4,650.74	.....	.....	.....	.....
Claborn.....	2,011.50	10	2,011.50	.....	.....	.....	.....	.....	.....	.....	.....
Clay.....	1,409.52	10	1,409.52	.....	Highway tax.....	15	6,328.03	.....	.....	.....	.....
Cocke.....	10,546.73	10	4,218.70	.....	Railroad and telegraph.....	.....	1,000.00	.....	.....	.....	.....
Coffee.....	2,212.43	10	2,212.43	.....	.....	.....	.....	.....	.....	.....	.....
Crockett.....	4,874.00	20	3,874.00	.....	.....	.....	.....	.....	.....	.....	.....
Cumberland.....	1,506.95	10	1,506.95	.....	Outside first district.....	10	39,065.58	.....	.....	.....	.....
Davidson.....	149,074.74	10	100,009.168	10,000.00	Bridge tax.....	10	1,241.14	600	5	1.00	3,000.00
Decatur.....	5,482.28	10	1,241.14	.....	.....	.....	.....	.....	.....	.....	.....
DeKalb.....	4,722.70	20	4,722.70	.....	.....	.....	.....	.....	.....	.....	.....
Dickson.....	1,986.65	10	1,986.65	.....	.....	.....	.....	.....	.....	.....	.....
Dyer.....	13,225.94	20	13,225.94	.....	.....	.....	.....	.....	.....	.....	.....
Fayette.....	7,583.80	20	7,583.80	.....	.....	.....	.....	.....	.....	.....	.....
Fentress.....	5,726.95	15	3,226.95	2,500.00	Donations.....	.....	10,000.00	2,500	5	1.00	12,500.00
Franklin.....	16,712.00	10	4,212.00	.....	.....	.....	.....	.....	.....	.....	.....
Gibson.....	27,577.24	20	17,577.24	.....	Levies by general court.....	25	2,000.00	1,000	6	.75	4,500.00
Giles.....	10,012.27	15	10,012.27	.....	General maintenance.....	20	11,250.00	2,000	5	1.50	15,000.00
Granger.....	9,983.40	12	1,883.40	1,600.00	Bridge tax.....	.....	2,545.84	.....	.....	.....	.....
Greene.....	31,596.10	25	5,346.10	.....	.....	.....	.....	.....	.....	.....	.....
Grundy.....	3,818.76	10	1,272.92	.....	.....	.....	.....	.....	.....	.....	.....

¹ This information was obtained partly from the report of the Comptroller of the Treasury and partly from county officers and private citizens.² Blank spaces in column under this head indicate that it was impossible to obtain information. Nearly all of the counties still make use of the statute labor tax, but records on this subject appear to be very incomplete and inaccurate.

[illegible]

TEXAS.

TABLE 20.—County revenue applied to roads and bridges in 1914.

County.	Total revenue applied to roads and bridges.	County road and bridge tax.		Other revenues.		Statute labor tax.				Cash in lieu of labor.
		Rate, cents per \$100.	Receipts.	Source.	Amounts obtained.	Number of men who worked.	Number of days worked.	Average daily wage.	Cash value.	
Anderson	\$47,000.00	30	\$40,000.00	Special road tax...	\$7,000.00					
Andrews										
Angelina	15,722.55	15	15,722.55							
Aransas				Transfer...	5,000.00	150	5	\$1.50	\$1,125.00	
Archer	15,125.00	15	9,000.00							
Armstrong	4,000.00	12	4,000.00							
Airasosa	25,000.00	15	25,000.00							
Austin	22,309.93		13,731.22	Fines, etc.	8,543.71	497	5	1.25	3,106.25	\$80.00
Bandera	7,026.36	15	3,830.11							
Bailey										
Bastrop	32,500.00	25	20,000.00							
Baylor	4,829.27	14	4,829.27							
Bee	55,000.00	30	25,500.00	County warrants.	29,500.00	5,000	2	1.25	12,500.00	
Bell										
Bexar	119,000.00	10	110,000.00							
Blanco	8,588.00	15	4,888.00	Transfer...		600	4	1.25	3,000.00	19,000.00
Borden	3,800.00	11	3,000.00	Donations.	800.00					700.00
Bosque	29,000.00	15	18,000.00		5,000.00	1,000	4	1.50	6,000.00	
Bowie	20,000.00	15	20,000.00							
Brazoria	27,463.67	15	27,463.67							
Brazos	53,863.41	15	10,023.41	County warrants.	40,000.00	931	3.3	1.25	3,840.00	
Brewster	12,984.06	15	12,984.06							
Briscoe	6,947.77	15	3,924.77			278	5	2.00	2,780.00	243.00
Brooks	3,100.00		2,850.00	Fines, etc.	250.00					
Brown	16,000.00	15	16,000.00							
Burleson	35,000.00	15	15,000.00	Special tax.	15,000.00	1,000	4	1.25	5,000.00	
Burnet	13,625.00	10	8,000.00			900	5	1.25	5,625.00	
Caldwell	15,000.00		15,000.00							
Calhoun										
Callahan	11,400.00	15	9,000.00			400	4	1.50	2,400.00	
Cameron	23,400.00	15	23,400.00							
Camp										
Carson	5,230.16	15	5,122.16			12	3	3.00	108.00	
Cass	31,000.00	15	10,500.00	Special road tax.	10,500.00	2,000	4	1.25	10,000.00	
Castro	2,024.16	5	1,524.16			50	5	2.00	500.00	
Chambers	5,778.00	15	5,778.00							

Cherokee	17,500.00	15	15,000.00	Special road tax...	11,000.00	500	5	1.00	2,500.00
Childress	13,251.84	25	13,251.84						2,60,000.00
Clay	31,000.00	15	20,000.00						
Cochran	1,153.83	15	1,153.83						
Coke	9,500.00	30	9,500.00						
Coleman	18,000.00	15	18,000.00						
Collin	43,892.46	15	43,892.46						
Collingsworth	10,000.00	15	5,000.00	Special road tax...	5,000.00				
Colorado	43,028.00	30	43,028.00						
Comal	21,159.78	14½	10,400.00	Special road tax...	10,759.78				
Comanche	15,000.00	15	15,000.00						
Concho	30,941.07	15	30,941.07						
Cooke	43,000.00	15	14,000.00	Special road tax...	14,000.00	2,000	5	1.50	15,000.00
Coryell	6,000.00	15	6,000.00						
Cottle									
Crane									
Crockett	20,000.00	10	20,000.00						
Crosby	4,774.50		4,774.50						
Culbertson									
Dallam	12,000.00		6,000.00	Special road tax...	6,000.00				
Dallas	180,000.00	15	180,000.00						
Dawson	4,977.50	5	1,500.00	Special road tax...	2,540.00	150	5	1.25	987.50
Deaf Smith	6,145.89		6,145.89						
Delta	27,559.00	30	15,000.00	Special road tax...	1,309.00	1,500	5	1.50	11,250.00
Denton	50,441.21		49,854.21	Fines	590.00				
De Witt	43,550.00	12½	24,250.00	Special road tax...	19,300.00				
Dickens	8,013.50	15	5,800.00	Fines	651.00	250	5	1.25	1,562.50
Dimmit	8,250.00	15	8,250.00						
Donley	18,100.00	15	8,100.00	Special road tax...	10,000.00				
Duval	7,088.02	15	7,088.02						
Eastland	14,812.00	15	14,812.00						
Ector									
Edwards									
El Paso	92,000.00	24½	92,000.00	Special revenue	13,093.00				
Ellis	68,600.43	15	55,507.43	do...	28,715.00				
Erath	46,715.00	15	18,000.00						
Falls	43,000.00	23	43,000.00						
Fannin	86,683.14	15	35,000.00	Commutation tax	51,683.14				
Fayette	28,855.26	15	28,728.82	Interest on cash deposits	126.44				
Fisher	34,000.00	15	12,000.00	Special tax and transfer funds	14,500.00	1,000	5	1.50	7,500.00
Floyd	26,772.50	15	13,240.00	Special tax...	13,532.50				
Foard									
Fort Bend	21,000.00	15	21,000.00						
Franklin	20,675.47	15	18,465.58	Special revenue	2,209.89				
Freestone	10,000.00	15	10,000.00						
Frio	14,500.00	30	14,500.00						
Gaines	3,952.37	15	3,952.37						
Galveston									
Garza	9,941.18	22	9,741.18			40	2½	2.00	200.00
Gillespie	18,550.00	12½	7,200.00			1,192	5	1.25	7,450.00
Goliad									3,900

1 Cash value of convict labor applied to roads.

² Cash value of free labor applied to roads.

³ No tax for roads 1914.

[illegible]

³ Surplus from general tax applied to roads.
⁴ No road tax except for sinking fund to retire bonds.

¹ Treasurer states there are no roads in county.

² Included in amount for general.

⁴ No road tax except for sinking fund to retire bonds.

TEXAS—Continued.
TABLE 20.—County revenue applied to roads and bridges in 1914—Continued.

County.	Total revenue applied to roads and bridges.	County road and bridge tax.		Other revenues.		Statute labor tax.				Cash in lieu of labor.
		Rate, cents per \$100.	Receipts.	Source.	Amounts obtained.	Number of men who worked.	Number of days worked.	Average daily wage.	Cash value.	
Moore.....	\$1,000.00	5	\$1,000.00							
Morris.....	12,750.00	30	8,500.00	Special improvement fund.	\$4,000.00	50	4	\$1.25	\$250.00	
Motley.....	3,284.30	7½	3,284.30							
Nacogdoches.....	14,427.12	15	14,427.12							
Navarro.....	39,175.09	15	39,175.09			600	2	1.50	1,800.00	\$2,000.00
Newton.....	16,800.00		13,000.00							
Nolan.....	12,600.00	15	12,600.00							
Nueces.....	22,000.00	15	22,000.00			150	5	1.50	1,125.00	
Ochiltree.....	2,737.54		1,612.54							
Oldham.....	3,585.47	10	3,585.47							
Orange.....	8,000.00	30	8,000.00							
Palo Pinto.....	30,000.00	25	30,000.00							
Panola.....	7,500.00	15	6,000.00							
Parker.....	36,250.00	25	36,000.00			500	2	1.25	1,250.00	1,500.00
Parmer.....	3,125.00		3,125.00							
Pecos.....										
Polk.....										
Potter.....	7,500.00	6	7,500.00							
Presidio.....	8,000.00	15	8,000.00							
Rains.....	4,000.00	15	4,000.00							
Randall.....	2,250.00	10	2,250.00							
Reagan.....										
Real.....	3,952.50	15	1,800.00			287	5	1.50	2,152.50	
Red River.....	68,750.00	15	18,750.00	Transfer from funds.	20,000.00	4,000	5	1.50	30,000.00	
Reeves.....	11,074.29	25	11,074.29							
Refugio.....	8,000.00	15	8,000.00							
Roberts.....	2,500.00	10	2,500.00							
Robertson.....	11,724.54	30	11,724.54							
Rockwall.....	7,463.62	15	7,463.62							
Runnels.....	18,000.00	15	12,000.00	Transfer funds.	6,000.00					
Rusk.....	11,000.00	30	11,000.00							
Sabine.....	6,000.00	15	6,000.00							
San Augustine.....	14,000.00	30	14,000.00			500	5	1.25	3,125.00	
San Jacinto.....	6,625.00	15	3,500.00							
San Patricio.....	59,000.00	15	59,000.00			1,200	5	1.50	9,000.00	
San Saba.....	23,000.00	15	14,000.00			150	5	2.00	1,500.00	
Schleicher.....	6,000.00	15	4,500.00							
Scurry.....	6,611.92	10	6,611.92							

	17,500.00	15	6,500.00	Special tax, 30 cents. Fines and deficiency warrants.	11,000.00					
Shackelford.....	45,500.00	30	21,000.00	Fines and forfeitures.	40.00	20	2	2.50	100.00	.....
Shelby.....						150	2	2.00	1,000.00	.....
Sherman.....	140.00		15,000.00							.....
Smith.....	15,000.00	15	1,670.00							.....
Somervell.....	2,670.00	15	3,159.58							.....
Starr.....	3,159.58	15	7,125.00							.....
Stephens.....	7,125.00	15	3,000.00							.....
Sterling.....	3,000.00	15	6,500.00	Fines.....	700.00					.....
Stonewall.....	7,200.00	15	6,300.00							.....
Sutton.....	6,650.00	21	6,882.92	Special levy, 15 cents.	5,000.00	20	5	1.75	175.00	350.00
Swisher.....	12,057.92	15	114,496.80	Fines, etc.	49,748.46	1,000	5	1.50	7,500.00	1,500.00
Tarrant.....	104,245.26	15	18,000.00							.....
Taylor.....	26,000.00		1,800.00							.....
Terrill.....	1,800.00	10	1,000.00							.....
Terry.....	1,000.00		1,000.00							.....
Throckmorton.....	12,500.00	30	12,500.00							.....
Thrus.....	7,541.00	15	7,541.00	Fines and interest.	2,000.00					.....
Tom Green.....	18,500.00	15	16,500.00	Fines and forfeitures.	1,000.00	2,500	3	1.50	11,250.00	110,000.00
Travis.....	104,250.00	20	82,000.00			750	5	1.00	3,750.00	.....
Trinity.....	13,262.54	15	9,512.54							.....
Trinity.....	9,500.00	15	9,000.00							.....
Tyler.....	13,000.00	30	13,000.00	Fines.....	50.00	20	5	2.00	200.00	105.00
Upshur.....	13,000.00	5	886.01							.....
Upton.....	1,251.01	15	13,000.00							.....
Uvalde.....	13,000.00	15	12,300.00							.....
Val Verde.....	12,500.00	15								.....
Val Verde.....										.....
Victoria.....										.....
Walker.....	10,027.38	15	10,027.38							.....
Waller.....	5,300.00	15	5,300.00							.....
Ward.....	5,818.16	15	5,435.66			85	3	1.50	382.50	.....
Washington.....	33,570.00	30	16,785.00	Special road and bridge tax.	16,785.00					.....
Webb.....	11,000.00	15	11,000.00							.....
Wharton.....	28,000.00	30	28,000.00							.....
Wheeler.....	10,800.00	30	10,800.00							.....
Wichita.....	32,146.52	15	32,146.52							.....
Willbarger.....	18,000.00	14	18,000.00							.....
Willacy.....	1,125.00	5	1,125.00							.....
Williamson.....	88,446.44		48,420.83	Donations and transfers	26,537.61	1,000	4	1.50	6,000.00	7,488.00
Wilson.....	15,000.00	15	15,000.00							.....
Winkler.....										.....
Wise.....	40,000.00	30	40,000.00							.....
Wood.....	18,500.00	15	15,000.00	Special tax.	3,500.00					.....
Yakum.....	981.45	8	981.45							.....
Young.....	17,000.00		17,000.00							.....
Zapala.....	636.12	12	636.12							.....
Zavalla.....	1,683.39		1,683.39							.....
Total.....	5,101,243.86		4,004,165.98		678,582.38				321,771.50	36,724.00

1 Cash value of convict labor applied to roads.

VIRGINIA.

TABLE 21.—County revenue applied to roads and bridges during 1914.

County.	Total revenue applied to roads and bridges.	Tax rate, cents per \$100.		County.	Total revenue applied to roads and bridges.	Tax rate, cents per \$100.	
		County.	Dist.			County.	Dist.
Accomac.....	\$20,671.49		25-35	Lancaster.....	\$8,615.34	45	
Albemarle.....	34,021.60		20	Lee.....	23,663.40	10	30-40
Alexandria.....	29,379.81		50	Loudoun.....	30,601.99	12 4	15-20
Alleghany.....	16,054.03	35		Louisa.....	10,347.09		25
Amelia.....	{ 2,490.16 } 7,765.74	35	10-15	Lunenburg.....	4,200.00		15-20
Amherst.....	13,549.78	10	20-25	Madison.....	5,240.40	20	
Appomattox.....	7,242.66		30	Mathews.....	2,237.98	30	
Augusta.....	176,713.81	25	20	Mecklenburg.....	17,058.90	25	
Bath.....	13,000.00	40		Middlesex.....	3,049.18	45	
Bedford.....	30,149.99	15	Varies.	Montgomery.....	12,000.00		25
Bland.....	7,734.76	20	40	Nansemond.....	4,050.32	20	15
Botetourt.....	234,600.00	45		Nelson.....	24,876.00		25
Brunswick.....	21,860.14	20	5-20	New Kent.....	3,500.00	10	20,30
Buchanan.....	18,507.08	20	20	Norfolk.....	127,799.59	20	
Buckingham.....	6,598.66	25		Northampton.....	10,529.15		15-20
Campbell.....	337,458.23		30-35	Northumberland.....	7,595.12	45	
Caroline.....	14,002.20		35	Nottoway.....	11,065.25		20,40
Carroll.....	18,783.68	50		Orange.....	10,549.06		10-25
Charles City.....	3,598.87	15	20	Page.....	11,065.38	20	20,25
Charlotte.....	8,000.00	50		Patrick.....	6,125.00	35	
Chesterfield.....	533,000.00	20		Pittsylvania.....	40,112.34	40	
Clarke.....	13,592.44	5	30	Powhatan.....	2,800.00	20	
Craig.....	5,700.00	10	30	Prince Edward.....	16,483.00	20	
Culpeper.....	13,065.26		20-40	Prince George.....	15,579.02		30,40
Cumberland.....	7,092.61	20	15	Prince William.....	1725,135.95	7 1/2	
Dickenson.....	7,683.36	20	20-30	Princess Anne.....	10,035.31		20
Dinwiddie.....	13,000.00	20		Pulaski.....	20,219.00		
Elizabeth City.....	5,500.00		15	Rappahannock.....	3,766.32		15
Essex.....	3,805.99	21 3/4		Richmond.....	3,278.49	30	
Fairfax.....	627,174.42		25	Roanoke.....	33,901.07	15	15
Fauquier.....	25,000.00	20		Rockbridge.....	27,037.31	11	25-35
Floyd.....	10,861.13	50		Rockingham.....	52,000.00	14	27 1/2
Fluvanna.....	4,000.00	20		Russell.....	16,312.56		30
Franklin.....	17,106.44	{ 5 } 5	25-40	Scott.....	13,344.33		25-40
Frederick.....	15,400.00	28		Shenandoah.....	20,897.73	25	20-25
Giles.....	10,000.00	25		Smyth.....	9,484.19		25,30
Gloucester.....	9,435.99	35	8-10	Southampton.....	30,000.00	45	30
Goochland.....	9,560.00	10	25	Spotsylvania.....	4,745.84		15,20
Grayson.....	716,933.15	33 3/4		Stafford.....	11,076.54	40	20-35
Greene.....	2,428.88	20		Surry.....	7,130.36	35	20
Greensville.....	17,773.89	10	40	Sussex.....	{ 197,000.00 } 21,300.00		20-40
Halifax.....	29,262.35	15	25-30	Tazewell.....	45,279.00		30
Hanover.....	32,581.37	15	25-30	Warren.....	7,521.80	30	20
Henrico.....	47,922.69	20	20	Warwick.....	2,879.77	10	10,20
Henry.....	13,000.00			Washington.....	25,000.00		50
Highland.....	4,898.19	15		Westmoreland.....	6,651.74		25-40
Isle of Wight.....	1010,575.20		15-20	Wise.....	11,880.01		10
James City.....	114,832.95	20		Wythe.....	12,199.40		20,25
King and Queen.....	5,500.00	15	25	York.....	5,290.90	5	20,30
King George.....	3,486.87	40					
King William.....	4,039.00	10	15-20	Total.....	1,687,906.00		

¹ Includes \$1,425 private subscriptions.² Includes \$7,500 private subscriptions.³ Includes \$5,000 from general county fund.⁴ Includes \$3,232.06 from general county fund.⁵ Includes \$10,000 from general county fund and \$1,000 private subscription.⁶ Includes \$7,447.85 special tax.⁷ Includes \$10,546 property tax worked out and \$2,387.15 from general county fund.⁸ Includes \$200 property tax worked out.⁹ Includes \$7,392.09 donations.¹⁰ Includes \$1,300 commutation tax and \$2,250 private subscriptions.¹¹ Includes \$1,500 from general county fund.¹² Bridge.¹³ Includes \$441.80 dog tax.¹⁴ Includes \$9,000 from county fund.¹⁵ Includes \$6,483 from dispensary.¹⁶ Includes \$3,981.80 county tax on railroads and steamboats.¹⁷ Includes \$6,000 joint funds.¹⁸ Includes \$1,500 from general county fund.¹⁹ County bridge.

WEST VIRGINIA.

TABLE 22.—County revenue applied to roads and bridges for fiscal year 1914-15.

County.	Total revenue applied to roads and bridges.	Permanent road tax.		Bridge tax.	General road tax.		Capita- tion tax, rate \$1 per capita.
		Rate, mills per \$1.	Receipts.		Rate, mills per \$1.	Receipts.	
Barbour.....	\$34,886	0.5	\$8,754	\$17,496	0.5	\$7,039	\$1,597
Berkeley.....	18,424	.5	10,803		.5	6,537	1,084
Boone.....	19,931			7,005	1.0	11,054	1,872
Braxton.....	12,296	.3	4,198		.5	5,622	2,476
Brooke.....	38,426	1.0	12,005	8,213	1.8	17,448	760
Cabell.....	31,756	.5	23,346		1.0	7,759	651
Calhoun.....	16,980	.5	2,171	9,417	1.0	4,340	1,052
Clay.....	6,566	1.0	5,514		.1	550	502
Doddridge.....	38,760				2.0	37,374	1,386
Fayette.....	91,353	2.0	48,912		1.0	33,081	9,360
Gilmer.....	20,088			4,792	1.6	14,122	1,174
Grant.....	20,300			11,155	1.4	8,009	1,136
Greenbrier.....	58,263	1.0	14,748	18,967	1.5	22,121	2,427
Hampshire.....	22,588	.06	446	10,704	1.2	10,140	1,298
Hancock.....	31,734	1.3	20,481		1.0	9,376	1,877
Hardy.....	16,637	1.0	5,593	3,916	1.2	4,742	2,386
Harrison.....	235,637	1.0	81,664	25,598	2.2	122,378	5,997
Jackson.....	34,478	.5	5,226	14,630	1.5	13,553	1,069
Jefferson.....	18,313	1.0	11,366		.5	5,684	1,263
Kanawha.....	¹ 149,165				¹ 149,165		
Lewis.....	60,378			24,027	1.6	33,886	2,465
Lincoln.....	48,439	.5	6,694	26,770	1.0	13,045	1,930
Logan.....	11,379	1.0	1,852		.4	6,599	2,928
Marion.....	117,589	.6	61,951		1.4	51,954	3,684
Marshall.....	39,231		2,886		1.5	35,086	1,259
Mason.....	46,217	.5	6,099	20,085	1.8	18,166	1,267
Mercer.....	61,754	1.2	43,502		1.0	16,058	2,194
Mineral.....	35,521	.5	7,878	12,605	1.5	14,115	923
Mingo.....	12,593	.2	5,663		.2	4,503	2,127
Monongalia.....	57,596	.5	26,040		.8	29,244	2,312
Monroe.....	24,252	.4	3,532	11,785	1.1	7,799	1,136
Morgan.....	18,885	1.0	7,591		1.0	9,498	1,496
McDowell.....	77,096	.9	41,520		.6	24,979	10,591
Nicholas.....	20,538	.5	7,214		1.0	11,209	2,105
Ohio.....	² 167,030				² 167,030		
Pendleton.....	12,703	.5	1,402	3,497	1.5	6,624	1,180
Pleasants.....	16,408		6,129		1.5	9,957	322
Pocahontas.....	46,005	1.0	11,035	15,120	1.3	16,838	3,012
Preston.....	38,761	.5	9,215	12,275	.8	14,742	2,529
Putnam.....	14,318	.5	5,058		1.0	8,734	526
Raleigh.....	26,079				.7	20,776	5,203
Randolph.....	48,815	.5	7,054	23,828	1.0	15,182	2,751
Ritchie.....	55,026			19,879	2.0	33,279	1,868
Roane.....	54,246	.5	14,897	11,809	1.5	25,386	2,154
Summers.....	13,275	1.0	6,646		.8	5,316	1,313
Taylor.....	41,767	.5	9,839	19,670	1.0	11,333	925
Tucker.....	26,249	.5	7,314	7,314	1.0	9,206	2,415
Tyler.....	46,047	1.0	15,606	13,828	1.0	15,606	1,007
Upshur.....	13,788	.09	1,173		1.0	11,318	1,297
Wayne.....	65,563	.5	9,769	37,782	1.0	15,702	2,310
Webster.....	19,827			8,476	1.3	9,967	1,384
Wetzel.....	91,735	.4	14,810	17,034	2.0	58,142	1,749
Wirt.....	7,542	1.0	4,604		.5	2,113	825
Wood.....	115,751	.9	47,565	45,810	.7	21,217	1,159
Wyoming.....	10,977	.5	5,593		.4	4,802	582
Total.....	2,479,981		656,594	463,487		1,249,505	110,395

¹ Unable to secure report from Kanawha County for 1914-15. Figures given are for 1913 and comprised the following items: Permanent road tax, \$19,479; appropriation from general county fund, \$125,000; and corporation tax, \$4,686.

² Unable to secure report from Ohio County for 1914-15. Figures given are for year 1913, and money was all appropriated from general county fund.

TABLES SHOWING ROAD AND BRIDGE BOND ISSUES.

The following tabulated arrangement of the road and bridge bond issues is referred to under the text of the respective States:

ALABAMA.

TABLE 23.—Road and bridge bonds and script, 1914.

County.	Amount of bond money expended during 1914 from all issues.	Total of all road and bridge bonds outstanding Jan. 1, 1915.	County.	Amount of bond money expended during 1914 from all issues.	Total of all road and bridge bonds outstanding Jan. 1, 1915.
Autauga.....		\$155,000	Limestone.....		\$135,000
Bibb.....		100,000	Madison.....		250,000
Blount.....	\$52,000	150,000	Marion.....	\$100,000	100,000
Bullock.....		160,000	Marshall.....	40,000	130,000
Coffee.....	3,000	3,000	Mobile.....		500,000
Colbert.....		200,000	Montgomery.....	300,000	825,000
Conecuh.....		125,000	Morgan.....		24,000
Crenshaw.....		75,000	Perry.....		110,000
Cullman.....	78,710	200,000	Pike.....		16,000
Dallas.....		60,000	Russell.....		192,000
Escambia.....		350,000	St. Clair.....		100,000
Etowah.....		38,000	Shelby.....	240,000	85,000
Fayette.....		200,000	Sumter.....		200,000
Hale.....		132,000	Tuscaloosa.....		120,000
Jackson.....		75,000	Walker.....	100,000	65,000
Lamar.....	75,000	250,000			130,000
Lawrence.....	24,500	123,000	Total.....	1,013,210	5,418,000

1 Warrants.

ARKANSAS.

TABLE 24.—Road and bridge bonds and script, 1914.

County.	Total road and bridge bonds and script outstanding, Jan. 1, 1915.	Bonds voted during 1914.	Bonds sold during 1914. ¹			
			Amount.	Interest rate.	Term.	Purchase price, cents per \$1.
				<i>Per cent.</i>	<i>Years.</i>	
Arkansas.....	\$20,000					
Baxter.....	200					
Carroll.....	700					
Chicot.....	2,500					
Clay.....	4,000					
Cleveland.....	898					
Craighead.....	6,000					
Gariand.....	29,000					
Hot Springs.....	500					
Independence.....	1,500					
Izard.....	672					
Jefferson.....	420,000	\$420,000	\$420,000	6	20	100
Johnson.....	15,000					
Lawrence.....	2,000					
Lee.....	96,000					
Lincoln.....	169,926	169,926	169,926	6	20	101
Lonoke.....	506,500	506,500	506,500	6	20	98
Miller.....	6,692					
Mississippi.....	2,000					
Monroe.....	12,000					
Montgomery.....	1,916					
Ouachita.....	5,000					
Pike.....	7,732					
Prairie.....	52,000	50,000	² 50,000	6	20	99
Pulaski.....	101,500	45,000	45,000	6	12	98
Saline.....	300					
Stone.....	30					
Union.....	500					
Woodruff.....	2,000					
Total.....	1,467,066	1,191,426	1,191,426			

¹ All bonds sold during 1914 were serial in character.² Of this amount \$45,000 was expended during 1914.

DELAWARE.

TABLE 25.—Road and bridge bonds, 1914.

County.	Total outstanding Jan. 1, 1915.	Bonds voted during 1914 and sold.		Expended from bond issues during 1914.
		Total.	Interest rate.	
Kent.....	\$30,000			\$22,000
New Castle.....	1,250,000	\$150,000	4½	340,000
Sussex.....				
Total.....	1,280,000	150,000		362,000

FLORIDA.

TABLE 26.—Road and bridge bonds, 1914.

County.	Total road and bridge bonds outstanding Jan. 1, 1915.	Total expenditure from bond issues during 1914.	Bonds voted during 1914.	Bonds sold during 1914.				Bonds retired in 1914.
				Amount.	Interest rate.	Term.	Rate of purchase price.	
					Percent.	Years.		
Alachua.....	\$25,000.00	\$6,500.00						\$6,500
Brevard:								
District 1.....	17,142.69	22,350.93						
District 4.....	28,527.78	39,336.99						
Dade.....	507,001.00	125,000.00	\$125,000	\$125,000	5	20	98	
Duval.....	1,000,000.00							
Franklin.....	20,000.00	9,000.00						9,000
Gadsden.....	350.00	17,963.85						
Hillsboro.....	1,400,000.00							
Holmes.....	33,000.00	33,000.00						
Lee.....	75,000.00							
Manatee.....	250,000.00							
Marion.....	83,177.75							
Nassau.....	180,000.00	90,000.00		180,000	5½	30	98½	
Orange.....	525,000.00			525,000	5			
Palm Beach.....	200,000.00	46,900.00						3,000
Pasco.....	150,000.00	150,000.00						
Pinellas.....	370,000.00							
St. Johns.....	650,000.00		650,000	650,000	5½	30	(1)	
St. Lucie.....	197,000.00	25,000.00	25,000	25,000	6	25	97½	
{ 2 25,000.00								
Seminole.....	200,000.00	200,000.00						
Suwanee.....	2 23,000.00							
Total.....	5,959,199.22	765,051.77	800,000	1,505,000				18,500

¹ Par and interest.² Warrants.

KENTUCKY.

TABLE 27.—Total of all road and bridge bonds outstanding Jan. 1, 1915.

County.	Amount.	County.	Amount.
Boyd.....	\$15,000	Montgomery.....	\$29,000
Carroll.....	32,000	Nelson.....	34,000
Christian.....	202,000	Nicholas.....	12,000
Garrard.....	17,000	Owen.....	140,000
Kenton.....	167,000		
Lewis.....	25,000	Total.....	705,000
Madison.....	32,000		

LOUISIANA.

TABLE 28.—*Road and bridge bonds, 1914.*

Parish. ¹	Total road and bridge bonds outstanding Jan. 1, 1915.	Amount of bond money expended during 1914.	Bonds retired during 1914.	Bonds voted during 1914.	Bonds sold during 1914.		
					Amount sold.	Term.	Purchase price.
Acadia.....	\$155,000.00			\$170,000.00	\$170,000.00	Years. 1-10	Par.
Allen.....	28,000.00	\$15,000.00		30,000.00			
Ascension.....	58,000.00	62,000.00		35,000.00	35,000.00	20	Par.
Assumption.....	29,000.00	19,000.00		48,000.00	48,000.00		Par.
Bossier.....				175,000.00	175,000.00		
Caddo.....	44,000.00	11,000.00		{ 44,000.00	44,000.00	1-4	Par.
East Baton Rouge..	36,000.00	37,000.00	\$1,000.00	{ 37,000.00	37,000.00	20	Par.
Iberia.....	56,500.00	10,000.00	7,500.00	186,000.00			
Iberville.....	2,335.26	5,388.69					
Jefferson.....	200,000.00	25,000.00					
Lafayette.....		10,000.00		25,000.00			
Lafourche.....				105,000.00			
Rapides.....	{ 128,000.00	30,000.00	16,000.00				
	{ 67,000.00						
Sabine.....	46,000.00			{ 24,000.00	16,000.00	4, 9	
				{ 32,000.00			
St. Charles.....	205,000.00	95,000.00		{ 95,000.00	95,000.00	30	
St. Landry.....	100,000.00			110,000.00			
St. Tammany.....	180,000.00			100,000.00	100,000.00	10	
Tangipahoa.....	125,000.00			180,000.00	180,000.00	20	
				50,000.00	50,000.00	10	Par and in- terest.
Vermilion.....	{ 10,000.00	28,000.00		72,000.00	72,000.00	10	
	{ 6,000.00						
Washington.....	113,000.00	139,000.00		139,000.00	139,000.00	10	
West Baton Rouge.				75,000.00			
Total.....	1,588,835.26	486,388.69	24,500.00	1,732,000.00	2 1,161,000.00		

¹ Corresponds with county in other States.² All bonds sold during 1914 bear 5 per cent interest.

MARYLAND.

TABLE 29.—*County road and bridge bonds, 1914.*

County.	Total outstanding Jan. 1, 1915.	Expended from bond issues during 1914.	Retired during 1914.
Alleghany.....	\$30,000.00		\$30,000.00
Anne Arundel.....		\$6,000.00	24,000.00
Dorchester.....	35,000.00	9,400.00	{ 67,000.00
Montgomery.....	26,000.00	7,100.00	{ 14,000.00
Queen Annes.....	16,542.36	4,000.00	{ 141,700.00
Worcester.....	7,000.00		{ 46,000.00
			{ 21,000.00
			{ 75,000.00
			{ 25,000.00
Total.....	114,542.36	26,500.00	443,700.00

NOTE.—During the year 1914 Montgomery County voted and sold road bonds amounting to \$26,000. These bonds bear 5 per cent interest and run from 11 to 15 years.

TABLE 29a.—*State road and bridge bonds, 1914.*

Character.	Amounts outstanding Jan. 1, 1915.	Interest rate, per cent.	Maturity.
Sinking fund.....	\$4,990,000	3.5	1923-1928
Do.....	1,000,000	4	1926-1929
Do.....	3,170,000	4	1927-1928
Deferred serial.....	3,250,000	4	1917-1930
Total.....	12,410,000		

MISSISSIPPI—Continued.
TABLE 30.—Road and bridge bonds, 1914—Continued.

County.	Beats and districts.	Total road and bridge bonds outstanding Jan. 1, 1915.	Expended from bond issues during 1914.	Bonds retired during 1914.	Bonds voted during 1914.	Bonds sold during 1914.		
						Amount sold.	Interest rate.	Term.
							<i>Per cent.</i>	<i>Years.</i>
Leflore.....		{ \$160,000.00	{ \$54,707.00					
Lincoln.....		140,000.00						
Lowndes.....		200,000.00	1,918.40					
Madison.....	Beat 2.....	100,000.00	50,000.00			50,000.00	6	10
Madison.....	Beat 3.....	215,000.00	30,000.00			60,000.00	6	
Marshall.....		16,000.00		\$1,000.00				
Montgomery.....	Beat 1.....	40,000.00	5,000.00					
Neshoba.....		100,000.00	99,000.00					
Newton.....		150,000.00	110,000.00					
Noxubee.....	Beats 1, 2, 3, and 5.....	416,000.00	138,000.00					
Oktibbeha.....		50,000.00						
Panola.....		50,000.00				50,000.00	6	
Pontotoc.....		20,000.00	20,000.00					
Pike.....	District.....	300,000.00	100,000.00			300,000.00	6	20
Quitman.....	Beat 5.....	25,000.00			\$25,000.00	25,000.00	6	
Rankin.....		30,000.00						
Scott.....	Beats 1 and 2.....	167,500.00	39,906.00		67,500.00	67,500.00	6	20
Sharkey.....		50,000.00						
Smith.....	{ Beat 1.....	104,000.00				{ 79,000.00		
Smith.....	{ Beat 2.....					{ 28,000.00		
Sunflower.....	County and beats 2, 3, 4, and 5.....	{ 165,000.00				{ 50,000.00		
		{ 135,000.00				{ 25,000.00	6	20
		{ 175,000.00				{ 25,000.00		
Tallahatchie.....		12,500.00						
Tallahatchie.....		12,500.00	3,837.65			16,000.00	6	20
Tippah.....		15,900.00						
Tishomingo.....		35,000.00						
Tunica.....		50,000.00						
Union.....		50,000.00						
Warren.....		328,700.00	160,000.00	7,000.00				
Washington.....		100,000.00						
Wayne.....		100,000.00	40,000.00					
Wilkinson.....		1,200.00						
Wilkinson.....		19,872.00						
Yalobusha.....	{ Beat 2.....	120,000.00				{ 50,000.00		
Yalobusha.....	{ Beat 4.....					{ 8,000.00	6	
Yazoo.....	Beats 1, 2, and 3.....	77,500.00	14,500.00					
Total.....		8,327,172.00	2,051,452.71	40,000.00	1,225,500.00	1,778,500.00		

NORTH CAROLINA.

TABLE 51.—Road and bridge bonds, 1914.

County.	Township.	Total road and bridge bonds outstanding on Jan. 1, 1915.	Bonds voted during 1914.	Bonds sold during 1914.
Alamance		\$200,000		
Alleghany	One township	50,000		
Anson	Wadesboro	50,000		
Ashe	Horse Creek	5,800		
Beaufort		50,000		\$50,000
Bertie	One township	5,000		
Do.		20,000		
Bladen	Carvers Creek	10,000		
Do.	Brown Marsh	10,000		
Brunswick	Lockwoods Folly	10,000		
Do.	Shallotte	10,000		
Do.	Town Creek	15,000		
Do.	Smithville	30,000		
Do.	Northwest	15,000	\$15,000	15,000
Do.	Town Creek	10,000	10,000	10,000
Buncombe		275,000		
Do.		75,000	75,000	75,000
Do.	Black Mountain	20,000		20,000
Do.		50,000		
Burke	Morganton	50,000		35,000
Cabarrus		105,000		
Do.		50,000		
Caldwell	Lovelady		25,000	
Carteret	Newport	3,000		
Do.	do.	5,000	5,000	5,000
Do.	Morehead	10,000		10,000
Catawba	Hickory	50,000		
Do.	Newton	50,000		
Chatham	Matthews and Oakland	20,000	20,000	20,000
Cherokee	Murphy	180,000		30,000
Do.	Marble District	68,000		
Do.	Valley Town	47,000		
Cleveland		175,000		
Do.	Nos. 4 and 6	150,000		
Do.	Nos. 3, 7, and 8	185,000	185,000	185,000
Do.	Nos. 4, 6, 7, and 8	100,000		
Davidson	Lexington	175,000		
Davie		65,000		
Duplin		30,000		
Do.	Island Creek	200,000		200,000
Edgecombe	Rocky Mountain	10,000		
Do.	Road district	100,000	100,000	100,000
Forsyth		100,000		
Franklin	Franklinton	60,000		
Do.	Louisburg	80,000		
Do.	do.	40,000		
Do.	Youngsville	40,000		
Gaston		300,000		
Gates	Holly Grove	6,500	6,500	1,000
Graham	Cheeah	15,000		
Granville		160,000		
Greene	Bullhead	20,000		20,000
Do.	Sugg	10,000		10,000
Do.	Jason	10,000		10,000
Do.	Olds	20,000		20,000
Do.	Ormandsville	20,000		20,000
Do.	Shine	10,000		10,000
Do.	Snow Hill	20,000		20,000
Guilford		300,000		
Halifax	Enfield	40,000		40,000
Do.	Halifax	60,000	60,000	60,000
Harnett	Barbecue	10,000	10,000	10,000
Do.	Black River	2,500	2,500	2,500
Do.	Hectors Creek	15,000	15,000	15,000
Do.	Lillington	20,000	20,000	20,000
Do.	Upper Little River	20,000	20,000	20,000
Haywood	East Fork	100,000	100,000	100,000
Do.	Waynesville	50,000		
Henderson		25,000	25,000	25,000
Do.	Edneyville	12,000		12,000
Do.	Hendersonville	50,000	50,000	50,000
Do.	Hoopers Creek	20,000	20,000	20,000
Hoke		50,000		
Iredell		400,000		
Jackson	Cullowhee	30,000		15,000
Do.	Dillsboro	15,000		15,000

NORTH CAROLINA—Continued.

TABLE 31.—Road and bridge bonds, 1914—Continued.

County.	Township.	Total road and bridge bonds outstanding on Jan. 1, 1915.	Bonds voted during 1914.	Bonds sold during 1914.
Jackson.....	Sylva.....	\$30,000		\$30,000
Johnston.....	Beulah.....	40,000	\$40,000	40,000
Do.....	Ingram.....	40,000	40,000	40,000
Do.....	Meadows.....	50,000	50,000	50,000
Lee.....		100,000		
Do.....	Sanford.....	15,000		
Lincoln.....		200,000		
McDowell.....	Marion.....	50,000		
Do.....	Nebo.....	10,000		
Do.....	Old Fort.....	20,000		
Macon.....	Franklin.....	90,000		90,000
Madison.....		300,000		150,000
Do.....	Mars Hill.....	20,000		20,000
Martin.....	Robertsville.....	15,000	15,000	15,000
Do.....	Williamstown.....	40,000	10,000	10,000
Mecklenburg.....		300,000		
Mitchell.....	Grassy Creek.....	30,000	30,000	30,000
Moore.....	Carthage.....	12,000		
Do.....	do.....	20,000		20,000
Do.....	Deep River.....	50,000		
Do.....	Greenwood.....	12,500		
Do.....	Mineral Springs.....	7,000		
Do.....	McNeill.....	10,000		
Do.....	Sand Hill.....	10,000		
Do.....	do.....	10,000		
Nash.....	Rocky Mountain district.....	70,000		70,000
Do.....	North Whitakers.....	50,000		
Do.....	Coopers Creek.....	10,000		
Do.....	Dry Wells.....	20,000		
Do.....	Griffin.....	10,000		
Do.....	Mannings.....	50,000		
Do.....	South Whitakers.....	10,000		
New Hanover.....		200,000		
Do.....		350,000		
Northampton.....	Jackson.....	16,000	16,000	16,000
Do.....	Rich Square.....	30,000		20,000
Onslow.....	Jacksonville.....	7,500	7,500	7,500
Orange.....		230,000		
Do.....	Hillsboro.....	40,000		
Pasquotank.....		10,000		
Pitt.....	Greenville.....	50,000		50,000
Polk.....		100,000		
Do.....	Tryon.....	12,000		
Richmond.....	Beaverdam.....	10,000		
Do.....	Blackjack.....	5,000		
Do.....	Marks Creek.....	15,000		
Do.....	Mineral Springs.....	5,000		
Do.....	Rockingham.....	25,000		
Do.....	Steele.....	15,000		
Do.....	Wolf Pitt.....	25,000		
Rockingham.....		54,000	30,000	30,000
Rutherford.....		250,000		
Sampson.....		80,000	25,000	25,000
Scotland.....	Laurel Hill.....	30,000		
Do.....	Spring Hill.....	20,000		
Do.....	Stewartsville.....	50,000		
Do.....	Williamson.....	30,000		
Stokes.....	Danbury.....	15,000		15,000
Do.....	Meadows.....	40,000		40,000
Do.....	Sauratown.....	50,000		50,000
Surry.....	Mount Airy.....	80,000		80,000
Vance.....		200,000		200,000
Warren.....	Warrenton.....	50,000	50,000	50,000
Wayne.....	Brogden.....	40,000		40,000
Do.....	Goldsboro.....	100,000		100,000
Wilson.....	Mount Olive.....		30,000	
Wilson.....	Wilson.....	100,000		
Yancey.....		150,000		150,000
Total.....		8,955,300	1,119,500	2,709,000

SOUTH CAROLINA.

TABLE 32.—*Road and bridge bonds, 1914.*

County.	Total road and bridge bonds outstanding Jan. 1, 1915.	Expenditures from bonds issued during 1914.	Bonds voted during 1914.	Bonds sold during 1914.			
				Amount.	Interest rate.	Term.	Purchase price.
Chesterfield:					<i>Per cent.</i>	<i>Years.</i>	
Alligator Township.....	\$35,000		\$35,000	\$35,000	6	40	Par.
Dillon.....	100,000	\$15,000					
Jasper.....	40,000		40,000	40,000		40	Do.
Kershaw.....	¹ 40,000						
Laurens.....	¹ 50,000						
Richland:							
Columbia Township.....	¹ 75,000						
Marion.....	100,000	19,000					
Sumter.....	20,000						
Total.....	460,000	34,000	75,000	75,000			

¹ Bridge bonds only.

TENNESSEE.

TABLE 33.—*Road and bridge bonds, 1914.*

County.	Total road and bridge bonds outstanding Jan 1, 1915.	Expenditures from bond issues during 1914.	Bonds retired during 1914.	Bonds voted during 1914.	Bonds sold in 1914.		
					Amount sold.	Interest rate.	Term in years.
Anderson.....	\$382,000.00	\$10,000.00	\$25,000.00	\$57,000.00	\$57,000.00	<i>Per ct.</i> 5	} 20-30
Bradley.....	226,000.00	10,000.00		50,000.00	50,000.00	5	
Carter.....	60,000.00			50,000.00	50,000.00	5	
Claiborne.....	70,000.00						
Cooke.....	500,000.00						
Davidson.....	140,000.00		50,000.00				
Grainger.....	100,000.00						
Greene.....	800,000.00	233,000.00					
Hamblen.....	273,000.00				3,000.00		
Hawkins.....	{ 203,000.00 }		5,000.00	24,500.00			63
Hickman.....	{ 24,500.00 }	3,000.00					
Loudon.....	{ 31,000.00 }	135,011.53		50,000.00	50,000.00	5	30
McMinn.....	{ 300,000.00 }						
Marion.....	{ 25,000.00 }		15,000.00				
Meigs.....	{ 125,000.00 }						
Monroe.....	{ 1,000.00 }						
Montgomery.....	{ 2,500.00 }						
Morgan.....	300,000.00						
Perry.....	300,000.00						
Putnam.....	125,000.00						
Roane.....	{ 300,000.00 }	103,929.48		110,000.00	110,000.00	5	30
Robertson.....	{ 457,000.00 }	68,419.82	14,421.11				
Sevier.....	{ 1,776.89 }	54,945.69	7,000.00				
Sullivan.....	{ 423,000.00 }	75,000.00					
Tipton.....	{ 38,500.00 }	5,000.00		25,000.00	25,000.00	5	25
Van Buren.....	{ 222,000.00 }						
Warren.....	{ 9,500.00 }		10,000.00				
White.....	{ 600,000.00 }						
	{ 25,000.00 }						
Total.....	6,898,276.89	778,306.52	128,421.11	486,500.00	445,000.00		

TEXAS.

TABLE 34.—Road and bridge bonds, 1914.

County.	Total outstanding Jan. 1, 1915.	Expendi- tures from bond issues during 1914.	Bonds retired during 1914.	Bonds voted during 1914.	Bonds sold during 1914.			
					Amount sold.	Inter- est rate.	Term	Rate of purchase price.
						P. ct. 5½	Yrs.	
Aransas.....				\$25,000.00				
Austin.....	\$175,000.00	\$24,393.43				5		
Bastrop.....				80,000.00				
Baylor.....	106,503.00	25,671.51				5		
Bell.....				761,990.00				
Bexar.....	1,377,500.00	531,151.82						
Borden.....	7,000.00							
Bosque.....	37,000.00		\$1,000.00					
Brazoria.....	217,955.00			50,000.00		5½		
Brazos.....	14,000.00							
Brooks.....	34,000.00	12,000.00		34,000.00	\$34,000.00	5	40	Cash.
Burnet.....				20,000.00		5		
Caldwell.....	50,000.00	50,000.00						
Calhoun.....				8,900.00		5		
Cameron.....	25,000.00			25,000.00	25,000.00	5	40	Par.
Cass.....	35,000.00	30,000.00						
Chambers.....	149,500.00	44,336.59	8,500.00					
Collin.....		63,975.00		865,000.00	865,000.00	5	40	Do.
Colorado.....	59,300.00	29,300.00	15,000.00	29,300.00	29,300.00	6	13-15	
Comal.....	124,000.00	70,000.00	1,000.00	17,000.00	17,000.00	5		Do.
Concho.....	11,000.00							
Cooke.....	97,990.00							
Crocket.....	40,000.00	15,000.00		40,000.00	15,000.00	5	40	Do.
Dallas.....				125,000.00		5		
Dimmit.....	40,000.00							
El Paso.....		308,724.35						
Fannin.....	250,000.00			250,000.00	250,000.00	5	40	Par and inter- est.
Fayette.....				45,500.00		5		
Fisher.....	21,899.00							
Foard.....	13,000.00							
Fort Bend.....	456,000.00	134,955.29	122,000.00					
Freestone.....	50,000.00							
Frio.....	84,000.00							
Garza.....				50,000.00		5		
Gonzales.....		10,182.37						
Gregg.....				50,000.00		5		
Grimes.....				100,000.00		5½		
Hardin.....	290,000.00			125,000.00				
Harris.....	2,508,000.00	842,787.16						
Harrison.....				300,000.00		5		
Hays.....	220,000.00	18,000.00	70,000.00	150,000.00	100,000.00	5	10-40	Par.
Hill.....				250,000.00		5		
Houston.....	178,000.00							
Howard.....	100,000.00							
Irion.....	20,000.00	8,000.00		20,000.00	20,000.00	5	40	Do.
Jeff Davis.....				10,000.00		5		
Johnson.....	56,200.00							
Jones.....	5,500.00							
Kendall.....				4,000.00		5		
Kerr.....				2,000.00		5		
Kimble.....				25,000.00		5		
Kinney.....				80,000.00		5		
Knox.....	13,000.00	6,000.00						
Lamar.....				50,000.00		5		
Lampasas.....	32,500.00			14,000.00	14,000.00	5	40	Do.
La Salle.....				40,000.00		5		
Lavaca.....				6,400.00		5		
Leon.....				40,000.00		5		
Liberty.....	485,100.00			60,100.00	60,100.00		40	Par and inter- est.
Live Oak.....	15,903.00		1,995.00					
McLennan.....	1,194,000.00	789,581.69		1,075,000.00	1,075,000.00	5	40	Par.
Matagorda.....				495,000.00		5½		
Maverick.....	42,602.00	2,800.00	3,000.00	25,000.00				
Medina.....	73,000.00	11,000.00						
Midland.....	48,000.00							
Milam.....				100,000.00		5½		
Mills.....	4,455.00							
Montgomery.....				200,000.00		5½		

¹ Voted in 1911 and sold in 1914.² Sold early in 1915.

TEXAS—Continued.

TABLE 34.—Road and bridge bonds, 1914—Continued.

County.	Total outstanding Jan. 1, 1915.	Expendi- tures from bond issues during 1914.	Bonds retired during 1914.	Bonds voted during 1914.	Bonds sold during 1914.			
					Amount sold.	In- ter- est rate.	Term	Rate of purchase price.
						<i>P. ct.</i>	<i>Yrs.</i>	
Navarro.....	\$175,000.00	\$300,000.00						Par.
Nolan.....	100,000.00							
Nueces.....	110,590.60	110,590.60	\$2,000.00	\$110,590.60	\$110,590.60	5	40	
Orange.....	226,995.00	170,000.00						
Palo Pinto.....	172,000.00			100,000.00		5½		
Panola.....	2,400.00							
Parker.....	25,000.00							
Pecos.....				85,000.00		6		
Potter.....	27,000.00	14,350.00						
Reeves.....	112,000.00			100,000.00		5		
Refugio.....	80,000.00	40,000.00						
Robertson.....	462,829.93	2,695.30	250.00	200,000.00				
Rockwall.....				2,500.00		5½		
Runnels.....	32,594.00	1,000.00	1,000.00					
San Patricio.....	118,000.00			10,000.00	10,000.00			
Scurry.....	15,000.00	40,000.00		50,000.00	50,000.00	5		
Schackelford.....	8,500.00		2,500.00					Do.
Smith.....	290,000.00	150,000.00	10,000.00	25,000.00	25,000.00	5	40	
Stephens.....	20,000.00		1,000.00					
Sterling.....	10,000.00							
Stonewall.....	50,000.00							Par and in- terest.
Tarrant.....	1,600,000.00							
Taylor.....	143,000.00		7,000.00					
Throckmorton.....	1,000.00	1,000.00	10.00					
Travis.....	350,000.00							
Trinity.....	160,000.00	135,000.00		100,000.00		5		
Upshur.....	40,000.00		4,000.00					
Victoria.....	387,200.00	91,916.83	3,000.00	171,995.00	170,000.00	5	40	
Walker.....	150,000.00	44,916.00		150,000.00	150,000.00	5	10-40	Do.
Waller.....	67,000.00	6,500.00		10,000.00		5		Do.
Wharton.....	400,000.00	4,628.78		100,000.00	100,000.00	5½	40	Do.
Wheeler.....	15,000.00							
Williamson.....	287,000.00		13,000.00					
Wood.....	150,000.00							
Zavalla.....	65,000.00	12,000.00		20,000.00		5		
Total.....	14,615,016.53	4,152,456.72	266,255.00	6,783,275.60	3,119,990.60			

¹ Not sold but contracted for.² Sold early in 1915.³ Warrants, not bonds.⁴ Balance sold early in 1915.

VIRGINIA.

TABLE 35.—*Road and bridge bonds, 1914.*

County.	District.	Total road and bridge bonds outstanding Jan. 1, 1915.	Amount of bond money expended during 1914.	Amount of bonds pre- viously is- sued retired in 1914.	Voted or issued during 1914. ¹			Purchase price.
					Amount voted.	Amount sold.	Interest rate.	
							<i>Per cent.</i>	<i>Years.</i>
Accomac.....	Three districts.....	\$58,569.93	\$17,631.28					
Amherst.....	South River.....	250,000.00	100,000.00					
Augusta.....		{ 7,000.00 }			\$17,000.00		5	25
Botetourt.....	Four districts.....	207,000.00	41,000.00		125,000.00		5	
Brunswick.....		3,000.00						
Buckingham.....		115,000.00						
Charlotte.....		40,000.00		\$40,000.00				
Culpeper.....	Salem, Catalpa, Stephen.....	{ 124,500.00 }	{ 271,057.54 }		36,000.00		5	2-30
Dickenson.....	Kenady.....	55,000.00	3 2,696.65					
Dimwiddle.....		32,000.00						
Fairfax.....	Mount Vernon.....	100,500.00	18,098.20			\$50,000.00	5	10-33
Fauquier.....	Center.....	50,000.00						
Greensville.....	Three districts.....	55,000.00	20,000.00					
Lee.....		400,000.00	42,000.00	438,000.00				
Lunenburg.....	Rehoboth.....					20,000.00	5½	30
Do.....	Plymouth.....	40,000.00						
Do.....	Lewiston.....							
Do.....	Brown Store.....	40,000.00				20,000.00	5½	30
Do.....	Locheven.....							
Do.....	Eight districts.....							
Mecklenburg.....		332,000.00	64,808.90	7,000.00	100,000.00			
Do.....	Blacksburg.....							
Montgomery.....		35,000.00						
Nelson.....		100,000.00	10,000.00					
Northampton.....		114,325.00	10,534.54	2,938.23				
Orange.....		10,000.00						
Page.....		100,000.00	25,529.51					
Pittsylvania.....		250,000.00	24,702.00					
Pulaski.....		45,000.00	19,847.06					
Rappahannock.....	Plans.....	20,000.00	16,000.00			10,000.00	5	
Rockingham.....		381,000.00	50,001.30	6,000.00				
Russell.....		149,000.00	59,758.71	1,000.00				
Do.....	Castlewood.....	100,000.00	19,000.00					
Scott.....	Estillville.....	33,300.00	8,000.00		100,000.00		5½	Par.
Do.....	Johnson.....	33,300.00	8,000.00		33,300.00		5½	Do.
Do.....	Fulkerson.....	33,800.00	8,000.00		33,800.00		5½	Do.

Smyth.....	St. Clair.....	75,000.00	15,452.40	.....	45,000.00	5	30	Par and interest.
Do.....	Marion.....	150,000.00	60,763.17	.....	90,000.00	5	30	Do.
Do.....	Rich Valley.....	100,000.00	16,261.95	.....	50,000.00	6	30	Do.
Spotsylvania.....	Four districts.....	123,000.00	.....	4,000.00	.....	.....	.....	.....
Stafford.....	Tazewell.....	100,000.00	.....	.....	.....	.....	.....	.....
Tazewell.....	.....	604,000.00	67,582.66	7,000.00	.....	.....	.....	.....
Warren.....	Front Royal.....	44,000.00	14,596.45	.....	70,000.00	5	30	.....
Washington.....	Kinderhook.....	14,000.00	.....	.....	.....	.....	.....	.....
Wise.....	.....	190,000.00	30,000.00	5,000.00	18,000.00	.....	.....	.....
Do.....	Richmond.....	700,000.00	.....	.....	.....	.....	.....	.....
Do.....	Gladville.....	130,000.00	166,544.62	.....	.....	.....	.....	.....
Do.....	.....	130,000.00	.....	.....	.....	.....	.....	.....
Total.....	.....	5,650,994.93	999,866.94	510,938.23	366,000.00	.....	.....	.....
.....	.....	.....	.....	.....	452,100.00	.....	.....	.....

¹ For all bonds issued or sold during 1914 special or regular levies were made for interest and retirement except in Rockingham County, where tolls were collected for that purpose.

² Catalpa.

³ Stephen.

⁴ Subject to call after fifth year.

WEST VIRGINIA.

TABLE 36.—*Road and bridge bonds, 1914.*

County.	Bonds out- standing July 1, 1915.	Bonds voted up to July 1, 1915.	County.	Bonds out- standing July 1, 1915.	Bonds voted up to July 1, 1915.
Barbour.....		¹ \$40,000	Preston.....	(²)	\$440,000
Cabell.....	\$280,000	300,000	Pleasants.....	(²)	¹ 60,000
Hancock.....	(²)	¹ 350,000	Summers.....	(²)	230,000
Harrison.....	110,000	110,000	Tyler.....	(²)	¹ 325,000
Kanawha.....	(²)	375,000	Upshur.....	(²)	181,000
Logan.....	(²)	¹ 60,000	Wetzel.....	(²)	150,000
Marion.....	300,000	¹ 700,000	Wood.....	110,000	¹ 180,000
Marshall.....	(²)	¹ 150,000	Wyoming.....	(²)	550,000
Mercer.....	500,000	850,000			
Monongalia.....	(²)	300,000	Total.....	1,303,000	5,354,000
Monroe.....	3,000	3,000			

¹ See Bulletin 136, U. S. Department of Agriculture.² Unable to ascertain date of bond sales in these counties.

MILES OF PUBLIC ROAD, STATE AND LOCAL, OUTSIDE INCORPORATED CITIES.

The following tables, referred to under the respective States, show the miles of public roads, State and local, outside of incorporated cities.

ALABAMA.

TABLE 37.—*Miles of all public roads, State and local, outside of incorporated cities, 1914.*

County.	Total mileage of all roads.	Surfaced roads.					Graded and drained earth.
		Macadam.	Gravel.	Sandclay.	Total surfaced.	Percent- age of all roads surfaced.	
Autauga.....	550			100	100	18.1	80
Baldwin.....	800		1	3	4	.5	74
Barbour.....	1,200			165	165	13.7	65
Bibb.....	600	6	3		9	1.8	46
Blount.....	1,000	5.5	35		40.5	4.0	33.5
Bullock.....	1,000		5	150	155	15.5	110
Butler.....	450			50	50	11.1	50
Calhoun.....	1,100	15	5		20	1.8	8
Chambers.....	1,000			10	10	.1	10
Cherokee.....	700		60		60	8.6	290
Chilton.....	1,018			18	18	1.7	18
Choctaw.....	350						
Clarke.....	1,000						20
Clay.....	1,000						2
Cleburne.....	800						5.5
Coffee.....	500			50	50	10.0	50
Colbert.....	550	75	55		130	23.6	30
Conecuh.....	500			180	180	36.0	94
Coosa.....	200			16	16	8.0	16
Covington.....	600			125	125	20.8	125
Crenshaw.....	1,047			97	97	9.2	97
Cullman.....	1,000		41		41	4.1	41
Dale.....	760			20	20	2.6	46
Dallas.....	1,100		125	12	137	12.4	105
DeKalb.....	1,500		25	6	31	2.0	1
Elmore.....	600		62	30	92	15.3	92
Escambia.....	535			22	22	4.1	22
Etowah.....	1,100	1	125		126	11.4	29
Fayette.....	1,100		5		5	.4	20
Franklin.....	400	5.5	17		22.5	5.6	22.5
Geneva.....	800			65	65	8.1	65
Greene.....	400		9	1	10	2.5	45

ALABAMA—Continued.

TABLE 37.—Miles of all public roads, State and local, outside of incorporated cities, 1914—Continued.

County.	Total mileage of all roads.	Surfaced roads.						Graded and drained earth.
		Macadam.	Gravel.	Sand clay.	Total surfaced.	Percentage of all roads surfaced.	Increase in surfaced road mileage over 1909.	
Hale.....	225	-----	5	25	30	13.3	29	50
Henry.....	800	-----	-----	7	7	.8	7	-----
Houston.....	800	-----	-----	30	30	3.7	25	50
Jackson.....	500	150	20	-----	170	34.0	50	10
Jefferson.....	1,975	¹ 15	385	-----	400	20.3	150	250
Lamar.....	1,500	-----	40	-----	40	2.6	5	45
Lauderdale.....	500	-----	60	-----	60	12.0	20	60
Lawrence.....	800	44	-----	-----	44	5.5	44	40
Lee.....	700	-----	-----	10	10	1.4	10	20
Limestone.....	500	-----	110	-----	110	22.0	50	25
Lowndes.....	400	-----	44	-----	44	11.0	34	30
Macon.....	400	-----	10	25	35	8.7	35	-----
Madison.....	600	50	300	-----	350	58.3	145	50
Marengo.....	1,100	-----	7	-----	7	.6	7	60
Marion.....	900	-----	28	72	100	11.1	100	-----
Marshall.....	1,000	8	15	-----	23	2.3	13	45
Mobile.....	2,350	² 37	100	200	337	14.3	67	-----
Monroe.....	1,600	-----	-----	-----	-----	-----	3	20
Montgomery.....	925	-----	650	50	700	75.6	387.07	25
Morgan.....	600	70	-----	-----	70	11.6	10	12
Perry.....	680	-----	18	22	40	5.8	40	-----
Pickens.....	800	-----	4	7	11	1.3	11	18
Pike.....	920	-----	-----	228	228	24.7	3	-----
Randolph.....	860	-----	-----	-----	-----	-----	-----	7
Russell.....	600	-----	2	75	77	12.8	77	-----
St. Clair.....	800	-----	100	-----	100	12.5	20	100
Shelby.....	851	-----	28	11	39	4.6	39	12
Sumter.....	700	-----	3	20	23	3.3	— 77	20
Talladega.....	825	-----	25	-----	25	3.0	— 25	100
Tallapoosa.....	650	-----	-----	-----	-----	-----	-----	50
Tuscaloosa.....	860	-----	56.5	-----	56.5	6.6	—161.5	45
Walker.....	1,015	-----	-----	-----	-----	-----	-----	110
Washington.....	650	-----	-----	-----	-----	-----	-----	100
Wilcox.....	800	1	-----	-----	1	.1	— 12	-----
Winston.....	1,000	-----	6	14	20	2.0	20	-----
Total.....	55,446	483	2,589.5	1,916	4,988.5	8.9	1,724.57	2,023.5

¹ Bituminous macadam.² Comprising 16 miles of bituminous macadam and 1 mile of concrete and 20 miles of shell.

NOTE.—This summary was made up from cards received from county officials, and has been revised and checked by Mr. R. P. Boyd, United States collaborator and assistant State highway engineer of Alabama.

ARKANSAS.

TABLE 38.—Miles of public roads outside of incorporated cities, 1914.

County	Total mileage of all roads.	Surfaced roads.						Graded and drained earth roads.
		Macadam.	Gravel.	Sand-clay.	Total surfaced.	Percentage of total surfaced.	Increase in surfaced mileage over 1909.	
Arkansas ¹	1,300	.....	.....	.....	.....	.....	.....	500
Ashley ¹	800	.....	.....	10	10	1.25	10	500
Baxter ¹	700	.....	.....	.....	.....	.....	— 25	350
Benton.....	803	2 3	.....	.....	3	.37	—122	100
Boone.....	1,000	.....	.....	.....	.....	.....	.....	300
Bradley ¹	400	.....	15	50	65	16.25	65	285
Calhoun ¹	485	.....	10	.....	10	2.06	10	400
Carroll ¹	910	.....	.....	.....	.....	.....	.....	760
Chicot ¹	320	.....	.....	60	60	18.75	60	235
Clark ¹	518	.....	12	.....	12	2.31	— 86	125
Clay ¹	1,200	.....	.....	.....	.....	.....	— 5	600
Cleburne.....	800	.....	.....	.....	.....	.....	.....	300
Cleveland.....	412	.....	.....	.....	.....	.....	.....	200
Columbia.....	800	.....	.....	.....	.....	.....	.....	200
Conway.....	700	3	.....	.....	3	.42	— 6	200
Craighead ¹	506.5	.....	72.5	.....	72.5	14.31	— 7.5	272
Crawford ¹	1,000	.....	.....	.....	.....	.....	.....	500
Crittenden.....	500	.....	.....	.....	.....	.....	.....	200
Cross.....	1,200	.....	4	.....	4	1.33	1	500
Dallas.....	600	.....	10	.....	10	1.66	10	90
Desha.....	300	.....	.....	.....	.....	.....	.....	.....
Drew.....	300	.....	15	.....	15	5.00	— 3	.....
Faulkner.....	1,200	.....	.....	.....	.....	.....	— 2	200
Franklin ¹	805	.....	.....	.....	.....	.....	.....	805
Fulton.....	350	.....	.....	.....	.....	.....	.....	150
Garland ¹	442	.....	32	.....	32	7.24	22	160
Grant.....	480	.....	.....	.....	.....	.....	.....	250
Greene.....	683	.....	25	.....	25	15.15	7	15
Hempstead.....	1,005	.....	.....	5	5	.49	5	800
Hot Springs ¹	600	.....	10	.....	10	1.66	10	390
Howard.....	600	.....	15	.....	15	2.50	— 10	95
Independence ¹	911	.....	.....	.....	.....	.....	— 27	500
Izard ¹	700	.....	.....	.....	.....	.....	.....	.....
Jackson.....	650	.....	.....	.....	.....	.....	— 1	90
Jefferson.....	650	3 36	15	.....	51	7.84	21	249
Johnson.....	650	.....	.....	.....	.....	.....	.....	50
Lafayette ¹	325	.....	35	15	50	15.38	50	200
Lawrence.....	365	10.5	3	.....	13.5	3.69	3.5	151.5
Lee ¹	700	.....	.....	.....	.....	.....	.....	450
Lincoln ¹	350	.....	18	.....	18	5.14	14	82
Little River ¹	270	.....	.....	.....	.....	.....	.....	150
Logan.....	850	.....	.....	.....	.....	.....	.....	50
Lonoke ¹	818	93.5	.....	.....	93.5	11.43	82.5	160
Madison ¹	1,000	.....	.....	.....	.....	.....	.....	50
Marion.....	700	.....	.....	.....	.....	.....	— 20	40
Miller ¹	475	1	22	.....	23	4.84	23	77
Mississippi ¹	600	.....	.....	.....	.....	.....	.....	300
Monroe.....	220	.....	.....	.....	.....	.....	.....	100
Montgomery ¹	666	.....	.....	.....	.....	.....	.....	400
Nevada ¹	400	.....	.....	.....	.....	.....	.....	100
Newton.....	500	.....	.....	.....	.....	.....	.....	.....
Ouachita.....	550	.....	20	10	30	5.45	27	100
Perry.....	175	.....	.....	.....	.....	.....	— 16	75
Phillips ¹	800	.....	.....	.....	.....	.....	.....	600
Pike ¹	540	.....	10	.....	10	1.85	10	50
Poinsett.....	315	.....	15	.....	15	4.76	15	200
Polk.....	575	.....	.....	.....	.....	.....	.....	50
Pope ¹	481	1	5	.....	6	1.24	3.75	175
Prairie ¹	1,023	12	.....	.....	12	1.17	12	38
Pulaski.....	508.5	4 135	63.5	.....	198.5	39	—158.5	88.5
Randolph ¹	925	.....	20	5	25	2.70	20	200
St. Francis.....	1,058	.....	8	.....	8	.75	8	300
Saline.....	575	.....	25	.....	25	4.34	— 15	100
Scott ¹	1,046	.....	.....	.....	.....	.....	.....	100
Searcy ¹	300	.....	10	20	30	10	30	150
Sebastian ¹	770	70	10	.....	80	10.38	41	300
Sevier ¹	648	.....	.....	.....	.....	.....	— 52	125

¹ Summary sheet was compiled from report of the Arkansas State Highway Department; otherwise it was prepared from reports secured from county officials.

² Bituminous macadam.

³ Includes 21 miles of concrete.

⁴ Includes 1 mile of bituminous macadam and 35.5 of macadam with Telford base.

ARKANSAS—Continued.

TABLE 38.—Miles of public roads outside of incorporated cities, 1914—Continued.

County.	Total mileage of all roads.	Surfaced roads.						Graded and drained earth roads.
		Macadam.	Gravel.	Sand-clay.	Total surfaced.	Percentage of total surfaced.	Increase in surfaced mileage over 1909.	
Sharp ¹	576							92
Stone ¹	400							50
Union ¹	1,202							200
Van Buren.....	600							
Washington.....	1,710	10			10	.58	3	500
White ¹	800						8	100
Woodruff.....	800	12			12	1.50	12	30
Yell.....	846		35		35	4.13		
Total.....	50,743	387	535	175	1,097	2.16	11.75	16,305

¹ Summary sheet was compiled from report of the Arkansas State Highway Department; otherwise it was prepared from reports secured from county officials.

DELAWARE.

TABLE 39.—Miles of public roads outside of incorporated cities, 1914.

County.	Total mileage, all roads.	Surfaced roads.							Graded and drained earth roads.
		Macadam.	Bituminous macadam.	Gravel.	Shell.	Total surfaced.	Percentage of total surfaced.	Increase in surfaced road mileage over 1909.	
Kent.....	1,600	4.5	3.5	1	10.5	19.5	1.21	19.5	20
New Castle.....	939	157	32			189	20.12	86.6	250
Sussex.....	1,135			20	15	35	3.08	—49.0	
Total.....	3,674	161.5	35.5	21	25.5	243.5	6.62	57.1	270

FLORIDA.

TABLE 40.—Miles of public roads outside of incorporated cities, 1914.

County.	Total mile- age of all roads.	Surfaced roads.								Graded and drained earth roads.	
		Macadam.		Shell.	Sand- clay.	Brick.	Other hard sur- faced roads.	Total sur- faced.	Per- cent- age of total sur- faced.		In- crease in sur- faced mileage over 1909.
		Plain.	Bitu- minous.								
Alachua.....	222	20			100	2		122	54.95	122	
Baker.....	200										30
Bay.....	95			8	12			20	21.05	20	75
Bradford.....	500										
Brevard.....	280	69		36				105	37.50	75	100
Calhoun.....	550										
Citrus.....	205	60						60	29.26	10	
Clay.....	300			2	2			4	1.33	4	100
Columbia.....	250				35			35	14	35	100
Dade.....	380						¹ 80	80	21.05	100	
De Soto.....	458						² 8	8	1.74	22	150
Duval.....	255	16	4.5	40	³ 19.5	⁴ 64		144	56.47	90.15	60
Escambia.....	295			40	20			60	20.33	60	85
Franklin.....	42			12				12	28.57	12	30
Gadsden.....	400				185			185	46.25	171	185
Hamilton.....	130				5			5	3.84	3	20
Hernando.....	470										10
Hillsboro.....	1,656			85		21.24		106.24	6.41	9.72	550
Holmes.....	543										43
Jackson.....	775										525
Jefferson.....	300										200
Lafayette.....	240				4			4	1.66	4	20
Lake.....	325				116		¹ 34	150	46.15	71.50	
Lee.....	285			30	30			60	21.05	40	25
Leon.....	308	5			78			83	26.94	67	100
Levy.....	450	3		3.50	25			31.5	7	27.50	5
Liberty.....	140				30			30	21.42	30	25
Madison.....	450										75
Manatee.....	575	15.18	17.05	24.02		1		57.25	9.95	57.25	6
Marion.....	900	200						200	22.22	100	100
Monroe.....	97	22						22	22.67	22	
Nassau.....	320			21				21	6.56	21	
Orange.....	325				100	57		157	48.30	42	150
Osceola.....	218	15				3		18	8.25	7	100
Palm Beach.....	360	150		10				160	44.44	160	100
Pasco.....	228	18	20		65			103	45.08	93	
Pinellas.....	140	48				25		73	52.14	73	14
Polk.....	691	8	1.25		67			76.25	11.03	93.75	15
Putnam.....	550			18	⁵ 66	8		92	16.72	69	55
St. Johns.....	105			20		65		85	80.95	69	
St. Lucie.....	458	69.75		13.25	54			137	29.89	92	102
Santa Rosa.....	500				50			50	10	30	200
Seminole.....	273				31	22		53	19.41	53	70
Sumter.....	220				6			6	2.72	34	
Suwanee.....	426				26			26	6.10	15	200
Taylor.....	58										24
Volusia.....	320	105			4			109	34.06	19	90
Wakulla.....	196	5.23						5.23	2.67	5.23	16
Walton.....	225				75			75	33.33	72	50
Washington.....	306									16	56
Total.....	17,995	829.16	42.80	362.77	1,205.50	268.24	122	2,830.47	15.72	1,078.12	3,686

¹ Sand-asphalt.² Clay soil.³ Includes 12.5 miles of gravel.⁴ Includes 12 miles of concrete.⁵ Includes 30 miles of gravel.

GEORGIA.

TABLE 41.—Miles of public roads outside of incorporated cities, 1914.

County.	Total mileage of all roads. ¹	Surfaced roads.						Graded and drained earth roads.
		Macadam.	Gravel.	Sand-clay.	Total surfaced.	Percentage of total surfaced.	Increase in surfaced mileage over 1909.	
Appling.....	800						— 15	160
Bacon ²	170							75
Baker.....	250						— 35	200
Baldwin.....	304						— 50	304
Banks.....	351						— 14	200
Barrow ²	334							100
Bartow.....	591	2	12	15	29	4.9	29	400
Ben Hill.....	300			220	220	73.3	170	80
Berrien.....	603			150	150	24.8	50	400
Bibb.....	349			115	115	32.9	15	234
Bleckley.....	781			200	200	25.6	200	60
Brooks.....	464							200
Bryan.....	340			50	50	14.7	30	50
Bulloch.....	749			400	400	53.4	350	200
Burke.....	790			300	300	37.9	150	200
Butts.....	375							250
Calhoun.....	295			130	130	44.0	130	165
Camden.....	315	³ 15			15	4.7	— 5	100
Campbell.....	660							200
Candler.....	250			40	40	16.0	40	120
Carroll.....	1,223	7		15	22	1.79	4	50
Catoosa.....	222	3	68		71	31.9	41	50
Charlton.....	227		25	10	35	15.4	35	120
Chatham.....	219		100		100	45.6	— 8	50
Chattahoochie.....	251							15
Chattooga.....	646		100		100	15.4	— 75	100
Cherokee.....	1,061						— 13	100
Clarke.....	152			87	87	57.2	32	65
Clay.....	226						— 40	200
Clayton.....	366			70	70	19.1	70	200
Clinch.....	323						— 10	300
Cobb.....	908						— 21	
Coffee.....	712						— 50	500
Colquitt.....	750			265	265	35.3	265	300
Columbia.....	366		15	15	30	8.1	10	300
Coweta.....	692			100	100	14.4	— 140	300
Crawford.....	650		27	10	37	5.7	37	500
Crisp.....	500			200	200	40.0	— 50	225
Dade.....	158						— 25	100
Dawson.....	293			15	15	5.1	15	100
Decatur.....	746			500	500	67.0	400	246
Dekalb.....	1,415	11	5	25	41	2.8	13	550
Dodge.....	1,423			80	80	5.6	55	500
Dooley.....	746						— 150	700
Dougherty.....	300			150	150	50.0	— 66	150
Douglas.....	402		100		100	24.8	100	125
Early.....	494			125	125	25.3	25	100
Echols.....	170							92
Effingham.....	335			84	84	25.0	84	78
Elbert.....	860							3
Emanuel.....	726			500	500	68.8	475	
Evans ²	225							100
Fannin.....	325							75
Fayette.....	379							250
Floyd.....	1,100	50	103		153	13.9	8	182
Forsyth.....	535							300
Franklin.....	532			100	100	18.7	100	200
Fulton.....	315	⁴ 198.12		2	200.12	63.5	— 104.88	
Gilmer.....	442							200
Glascok.....	140						— 35	100
Glynn.....	162	³ 23		20	43	26.5	— 110	100
Gordon.....	656							200
Grady.....	488			50	50	10.2	50	300
Greene.....	739	5	6	6	17	2.3	6	536
Gwinnett.....	779			100	100	12.8	100	400
Habersham.....	406	⁵ 12			12	2.9	11	100
Hall.....	1,385	⁶ 77			77	5.5	69	75
Hancock.....	792			200	200	25.2	185	550
Haralson.....	1,130							350
Harris.....	689			44	44	6.3	44	75

¹ Total mileage taken from report of secretary of state and represents 1915 mileage.² New county.³ Shell.⁴ Brick, 0.72 mile; concrete, 0.40 mile; bituminous macadam, 75 miles.⁵ Bituminous macadam.⁶ Seventy-three miles not classified.

GEORGIA—Continued.

TABLE 41.—Miles of public roads outside of incorporated cities, 1914—Continued.

County.	Total mileage of all roads.	Surfaced roads.						Graded and drained earth roads.
		Macadam.	Gravel.	Sand-clay.	Total surfaced.	Percentage of total surfaced.	Increase in surfaced mileage over 1909.	
Hart.....	516							200
Heard.....	612			10	10	1.6	2	180
Henry.....	1,400			50	50	3.5	50	400
Houston.....	1,248			250	250	20.0	200	500
Irwin.....	401			200	200	49.8	120	100
Jackson.....	576							262
Jasper.....	554			150	150	27.0	150	300
Jeff Davis.....	280			10	10	3.5	10	40
Jefferson.....	525			75	75	14.2	25	40
Jenkins.....	317						— 30	100
Johnson.....	316			150	150	47.4	115	150
Jones.....	427		25	20	45	10.5	—155	20
Laurens.....	1,500			200	200	13.3	135	1,300
Lee.....	550						— 75	550
Liberty.....	564			150	150	26.5	148	50
Lincoln.....	280							100
Lowndes.....	469			150	150	31.9	100	694
Lumpkin.....	350							100
McDuffie.....	310			50	50	16.1	— 50	140
McIntosh.....	190	17		45	52	27.3	47.5	8
Macon.....	523			375	375	71.7	342.5	100
Madison.....	516			50	50	9.6	—150	300
Marion.....	417			95	95	22.7	45	50
Meriwether.....	924							808
Miller.....	285			250	250	87.7	250	
Milton.....	290							
Mitchell.....	589			300	300	50.9	245	150
Monroe.....	821			300	300	36.5	300	
Montgomery.....	355			105	105	29.5	105	250
Morgan.....	450			100	100	22.2	— 25	100
Murray.....	385			20	20	5.1	10	100
Muscogee.....	229		25	75	100	43.6	— 31	100
Newton.....	410		5	28	33	8.0	— 22	200
Oconee.....	227							150
Oglethorpe.....	1,216		200		200	16.4	125	300
Paulding.....	692							25
Pickens.....	362							25
Pierce.....	273						— 2	250
Pike.....	1,000			100	100	10.0	80	500
Polk.....	457						— 65	350
Pulaski.....	288						—100	200
Putnam.....	500						— 15	100
Quitman.....	196			85	85	43.3	85	100
Rabun.....	322							200
Randolph.....	564			300	300	53.1	194	250
Richmond.....	500		124	281	405	81.0	239	
Rockdale.....	240						— 7.5	50
Schley.....	482			121	121	25.1	118	
Screven.....	247			255	55	22.2	5	100
Spalding.....	800	31		11	12	1.5	— 18.5	450
Stephens.....	386						— 14	230
Stewart.....	445			82	82	18.4	47	
Sumter.....	1,312			350	350	26.6	280	448
Talbot.....	412		2	10	12	2.9	12	230
Taliaferro.....	243							150
Tattnall.....	405			150	150	37.0	95	200
Taylor.....	381			10	10	2.6	5	25
Telfair.....	595			82	82	13.7	32	300
Terrell.....	410						—125	300
Thomas.....	720			50	50	6.9		350
Tift.....	241			100	100	41.4	11	100
Toombs.....	257			100	100	38.9	100	75
Towns.....	270							
Troup.....	700			200	200	28.5	175	200
Turner.....	800			200	200	25.0	100	205
Twiggs.....	400			100	100	25.0	100	300
Union.....	375							
Upson.....	750							400
Walker.....	600	80	80		160	26.6	— 74	25
Walton.....	606			30	30	4.9	30	170
Ware.....	300		1	25	26	8.6	22	115
Warren.....	293			25	25	8.5	25	164
Washington.....	737			250	250	33.9	50	200

¹ Shell.² Surfaced mileage computed by allowing 10 per cent increase over the 1909 surfaced mileage.³ Brick.⁴ Fifty miles not classified.

GEORGIA—Continued.

TABLE 41.—Miles of public roads outside of incorporated cities, 1914—Continued.

County.	Total mileage of all roads.	Surfaced roads.						Graded and drained earth roads.
		Macadam.	Gravel.	Sand-clay.	Total surfaced.	Percentage of total surfaced.	Increase in surfaced mileage over 1909.	
Wayne.....	570			25	25	4.3	17	275
Webster.....	266			35	35	13.1	30	190
Wheeler ¹	232							100
White.....	700							
Whitfield.....	507		50		50	9.8	45	
Wilcox.....	775			50	50	6.4	45	100
Wilkes.....	453			100	100	22.0	75	150
Wilkinson.....	1,100			100	100	9.0	100	600
Worth.....	631			150	150	23.7	150	600
Total.....	80,669	491.12	1,073	10,778	12,342.12	15.3	6,364.12	30,554

¹ New county.

KENTUCKY.

TABLE 42.—Miles of public roads outside of incorporated cities, 1914.

County.	Total mileage of all roads.	Surfaced roads.						Graded and drained earth roads.
		Macadam.		Gravel.	Total surfaced.	Per- centage of total surfaced.	Increase in surfaced mileage over 1909.	
		Plain.	Bitumi- nous.					
Adair.....	300	10			10	3.33	— 15	
Allen.....	425			50	50	11.76	43	25
Anderson.....	208						—200	
Ballard.....	425			24	24	5.64	24	
Barren.....	1,100	60		50	110	10	56	300
Bath.....	450	200		12	212	47.11	47	
Bell.....	150	2.5			2.5	1.66	— 1.5	
Boone.....	375	130		5	135	36	37.25	115
Bourbon.....	320	300			300	93.75	300	
Boyd.....	207	5			6.7	3.24	— 9	50
Boyle.....	250	110		30	140	56	—135	10
Bracken.....	450	300	1.7		300	66.66	120	
Breathitt.....	100							
Breckinridge.....	1,200	10		4	14	1.16	14	50
Bullitt.....	348	44		13	57	16.09	2	
Butler.....	475	5			5	1.05	5	70
Caldwell.....	430	20		1	21	4.88	1	279
Calloway.....	590			100	100	16.94	55	190
Campbell.....	300	200			203	67.33	128	
Carlisle.....	403			3	3	.74	3	
Carroll.....	300	175	3	25	200	66.66	39	100
Carter.....	400							40
Casey.....	975			75	75	7.77	10	
Christian.....	1,200	250			250	20.83	— 10	600
Clark.....	360	240		10	250	69.44	42	
Clay.....	500							
Clinton.....	200							
Crittenden.....	500	3			3	.60	3	
Cumberland.....	300	3			3	1	3	
Davies.....	732	46			46	6.28	1	296
Edmonson.....	200	5			5	2.50	— 3	
Elliott.....	264							
Estill.....	336							8
Fayette.....	386	370			382	98.96	22	
Fleming.....	645	235		40	275	42.63	50	
Floyd.....	400		12					
Franklin.....	400	300			300	75	71.50	100
Fulton.....	212							201.5
Gallatin.....	280	130		25	155	55.35	— 16	25
Garrard.....	226	126			126	55.75	— 9	
Grant.....	540	490			490	90.74	140	
Graves.....	1,350			200	200	14.81	188	200
Grayson.....	650	5.5			5.5	.84	2.5	15.5
Green.....	700						— 12	
Greenup.....	500			2	2	.40	.5	
Hancock.....	440							400
Hardin.....	1,070	150		20	170	15.88	— 15	700

KENTUCKY—Continued.

TABLE 42.—Miles of public roads outside of incorporated cities, 1914—Continued.

County.	Total mileage of all roads.	Surfaced roads.						Graded and drained earth roads.
		Macadam.		Gravel.	Total surfaced.	Per- centage of total surfaced.	Increase in surfaced mileage over 1909.	
		Plain.	Bitumi- nous.					
Harlan.....	250							
Harrison.....	500	350			350	70	— 15	
Hart.....	610	90			90	14.75	22	110
Henderson.....	635	50		20	70	11.02	— 36	565
Henry.....	420	270			270	64.28	20	
Hickman.....	600							
Hopkins.....	655							610
Jackson.....	500							
Jefferson.....	908	¹ 754.75	10	15	779.75	85.89	² 527.75	120
Jessamine.....	332	252			252	75.90	49	
Johnson.....	700	⁵			⁵		— .50	4
Kenton.....	325	² 230	7		237	72.92	18	60
Knott.....	300							
Knox.....	198							48
Larue.....	400	26		10	36	9	1	300
Laurel.....	1,000	10			10	1	6	
Lawrence.....	600							200
Lee.....	200							
Leslie.....	250							
Letcher.....	402							2
Lewis.....	700	15			15	2.14	— 65	
Lincoln.....	646	60		86	146	22.60	—136.5	120
Livingston.....	450							16.5
Logan.....	1,025	200		25	225	21.95	135	
Lyon.....	300	2			2	.66	2	
McCracken.....	540			320	320	59.25	168	170
McCreary.....	400							
McLean.....	500							150
Madison.....	657	209		26	235	35.76	—131	75
Magoffin.....	600							
Marion.....	500	140		25	165	33	15	
Marshall.....	600			150	150	25	90	400
Martin.....	200							1
Mason.....	410	340			340	82.92	— 30	
Meade.....	350	32			32	9.14	22	2
Menifee.....	200							5
Mercer.....	450	300			300	84.44	65	50
Metcalfe.....	353							3.5
Monroe.....	553	8		5	13	2.35	13	
Montgomery.....	300	125			125	41.66	15	
Morgan.....	600							
Muhlenberg.....	700							300
Nelson.....	480	220	25	25	270	56.25	— 17	150
Nicholas.....	325	265		4	269	82.76	13	
Ohio.....	850			8.5	8.5	1	.5	600
Oldham.....	275	125			125	45.45	40	150
Owen.....	600	400			400	66.66	85	
Owsley.....	300							
Pendleton.....	500	350			350	70	40	
Perry.....	200							
Pike.....	600							
Powell.....	75							
Pulaski.....	2,030	30			30	1.47	— 5	2,000
Robertson.....	135	75			75	55.55	10	60
Rockcastle.....	400							
Rowan.....	300							
Russell.....	400	5			5	1.25		
Scott.....	400	350			350	87.50	— 13	
Shelby.....	702	402			402	57.26	— 3	
Simpson.....	300	80		60	140	46.66	24	40
Spencer.....	322	22		100	122	37.88		
Taylor.....	250	1.5		11.5	11.5	4.50	— 43.5	30
Todd.....	450	25		5	30	6.66	— 5	100
Trigg.....	500			20	20	4	— 10	5
Trimble.....	300	80			80	26.66	15	30
Union.....	510							380
Warren.....	1,000	300		100	400	40	125	200
Washington.....	535	260		10	270	50.40	21	35
Wayne.....	426	26			26	6.10	1	
Webster.....	500							
Whitley.....	300						— 5	
Wolfe.....	300							
Woodford.....	260	225	0.33		225.33	86.55	23.33	
Total.....	57,916	10,630.75	59.03	1,713.50	12,403.28	21.4	2,288.33	10,867

¹ Includes $\frac{1}{4}$ mile of brick and $\frac{1}{2}$ mile of concrete.² Increase over 1904. No report for 1909.³ Includes 2 miles of concrete.

LOUISIANA.

TABLE 43.—Miles of public roads outside of incorporated cities, 1914.

Parish.	Total mileage of all roads.	Surfaced roads.							Graded and drained earth roads.
		Gravel.	Sand-clay.	Shell.	Other hard surfaced roads.	Total surfaced.	Percentage of total surfaced.	Increase in surfaced mileage over 1909.	
Acadia.....	674								450
Allen.....	150								
Ascension.....	241	21				21	8.71	21	220
Assumption.....	130	40				40	30.76	40	90
Avozelles.....	800								
Beauregard.....	150								75
Bienville.....	670								
Bossier.....	416	42	100						
Caddo.....	505	74.5			28 macadam.	170	40.86	170	60
					4 macadam.	81	16.03	77	4
					2.5 bituminous macadam.				
Calcasieu.....	500	40		6.5	15 brick	61.5	12.30	59.5	200
Caldwell.....	298	3				3	1	3	5
Cameron.....	100								
Catahoula.....	300							-15	40
Claiborne.....	750								
Concordia.....	300								
De Soto.....	400		100			100	25	25	100
East Baton Rouge.....	407	49			0.6 concrete	49.6	12.20	33.6	357
East Carroll.....	250		50			50	20	50	35
East Feliciana.....	400	.5				.5	.12	.5	
Evangeline.....	600								400
Franklin.....	350								
Grant.....	250	4				4	1.60	2	64
Iberia.....	342				12 concrete	12	3.50	12	30
Iberville.....	110	60				60	54.54	54.5	40
Jackson.....	375								120
Jefferson.....	126	2		44	10 pyrites	56	44.44	51	
Jefferson Davis.....	600								250
Lafayette.....	800								800
Lafourche.....	225								75
La Salle.....	350								200
Lincoln.....	650								50
Livingston.....	525								525
Madison.....	200		10			10	5	10	50
Morehouse.....	500								300
Natchitoches.....	800	15				15	1.87	15	
Orleans.....									
Ouachita.....	608	8	300			308	50.65	280	200
Plaquemines.....	136			32		32	23.52	32	
Pointe Coupee.....	325								
Rapides.....	1,309	9	700			709	54.16	706	200
Red River.....	275								
Richland.....	345							-60	20
Sabine.....	743								43
St. Bernard.....	43	3	5	25	10 cinders	43	100	7	
St. Charles.....	153	28				28	18.30	28	
St. Helena.....	325								
St. James.....	106	1				1	.94	1	55
St. John the Baptist.....	72								32
St. Landry.....	824	24				24	2.91	24	700
St. Martin.....	175								
St. Mary.....	202							-15	120
St. Tammany.....	300								180
Tangipahoa.....	300	1				1	.33	1	50
Tensas.....	251								
Terrebonne.....	220							-5	
Union.....	315								
Vermilion.....	450								200
Vernon.....	640								40
Washington.....	550		183			183	33.27	183	367
Webster.....	400	5				5	1.25	5	275
West Baton Rouge.....	100								50
West Carroll.....	250								11
West Feliciana.....	275								100
Winn.....	627								270
Total.....	24,563	430	1,448	107.5	82.1	2,067.6	8.42	1,796.1	7,453

¹ All included in city of New Orleans.

MISSISSIPPI—Continued.

TABLE 45.—*Miles of public roads outside of incorporated cities, 1914—Continued.*

County.	Total mileage of all roads.	Surfaced roads.						Graded and drained earth roads.
		Gravel.	Sand-clay.	Other hard surfaced roads.	Total surfaced.	Percentage of total surfaced.	Increase in surfaced mileage over 1909.	
Hancock.....	235			¹ 16	16	6.80	16	219
Harrison.....	999	10	1.25	¹ 63	74.25	7.43	54.25	725
Hinds.....	860	110			110	12.79	110	750
Holmes.....	921	5	1		6	.65	6	610
Issaquena.....	145							125
Itawamba.....	810	23	12		35	4.32	10	75
Jackson.....	429			² 4 ¹ 35	39	9.09	39	390
Jasper.....	803		3		3	.87	3	175
Jefferson.....	439							
Jefferson Davis.....	365							
Jones.....	747	9.5	13		22.5	3.01	22.5	
Kemper.....	1,110		10		10	.90	10	
Lafayette.....	700						— .75	70
Lamar.....	400							400
Lauderdale.....	800	51.75	95		146.75	18.37	143.75	
Lawrence.....	380							
Leake.....	840							50
Lee.....	312	145		³ 12	157	50.32	149	155
Leflore.....	650	23.75			23.75	3.65	23.75	616
Lincoln.....	207	54.6			54.6	26.42	54.60	
Lowndes.....	408	20	203		223	54.65	223	185
Madison.....	500							350
Marion.....	400							300
Marshall.....	750							
Monroe.....	650	75	20	⁴ 55	150	23.07	130	50
Montgomery.....	500							70
Neshoba.....	800	19			19	2.37	19	
Newton.....	599	22			22	3.67	22	
Noxubee.....	1,000	55	48		103	10.30	103	20
Oktibbeha.....	833			⁴ 31 ⁵ 1.5	32.5	3.90	32.5	
Panola.....	700							700
Pearl River.....	800							
Perry.....	500							
Pike.....	560	60			60	10.71	60	
Pontotoc.....	900		100		100	11.11	100	
Prentiss.....	455	30	25		55	12.02	45	200
Quitman.....	300							200
Rankin.....	400		1	³ 2	3	.75	3	200
Scott.....	652	40			40	6.13	40	12
Sharkey.....	250							40
Simpson.....	601							601
Smith.....	600							70
Sunflower.....	604	4			4	.66	— 46	350
Tallahatchie.....	520	10			10	1.92	10	220
Tate.....	450							
Tippah.....	525							100
Tishomingo.....	750							
Tunica.....	287	4	1		5	1.74	5	196
Union.....	512							103
Walshall.....	433							
Warren.....	416	48		⁵ 28 ⁶ .5	76	18.25	40	300
Washington.....	500				.5	.09	.5	350
Wayne.....	900							550
Webster.....	500							
Wilkinson.....	450							300
Winston.....	700							
Yalobusha.....	550							400
Yazoo.....	838	10			10	1.19	7	408
Total.....	45,779	1,281.10	604.25	248	2,133.35	4.66	1,791.10	13,686

¹ Shell. ² Slag. ³ Concrete. ⁴ Macadam. ⁵ Bituminous macadam. ⁶ Burnt clay.

NORTH CAROLINA.

TABLE 46.—*Miles of public roads outside of incorporated cities, 1914.*

County.	Total mileage of all roads.	Surfaced roads.						Graded and drained earth roads.
		Macadam.	Gravel.	Sand- clay.	Total sur- faced.	Per- centage of total surfaced.	Increase in surfaced mileage over 1909.	
Alamance.....	600	50		8	58	9.66	— 7	8
Alexander.....	200							
Alleghany.....	300							20
Anson.....	500	15	66	32	113	22.6	103	13
Ashe.....	500							
Avery.....	300							
Beaufort.....	400			4	4	1	4	
Bertie.....	800			20	20	2.5	— 15	200
Bladen.....	200			6	6	3	6	20
Brunswick.....	400			48	48	12	37	20
Buncombe.....	700	75		48	123	17.57	57	378
Burke.....	300			10	10	3.33	10	25
Cabarrus.....	600	22		45	67	11.16	7	50
Caldwell.....	500	3		6	9	1.8	— 35	35
Camden.....	200							
Carteret.....	200			20	20	10	20	10
Caswell.....	400	1.5			1.5	.37	— 14.5	
Catawba.....	450			100	100	22.22	100	20
Chatham.....	600						— 8	4
Cherokee.....	400	13		32	45	11.25	35	35
Chowan.....	185							
Clay.....	135							
Cleveland.....	800		25	80	105	13.12	100	15
Columbus.....	1,150		2	35	37	2.34	25	250
Craven.....	930			4	4	.43	— 22	35
Cumberland.....	600			105	105	17.5	65	175
Currituck.....	100			3	3	3	3	
Dare.....	70							
Davidson.....	800	3		10	13	1.62	11	10
Davie.....	263			57	57	21.67	57	10
Duplin.....	800			66	66	8.25	66	10
Durham.....	450	97	16	15	118	26.22	16	15
Edgecombe.....	750			20	20	2.66	10	10
Forsyth.....	750	2 74	5	50	129	17.86	83	10
Franklin.....	500	3 5		205	210	42	130	5
Gaston.....	500	110		40	150	30	82	5
Gates.....	300							20
Graham.....	250			3	3	1.2	3	2
Granville.....	700			135	135	19.28	37	
Greene.....	300			40	40	13.33	40	
Guilford.....	1,000	110	10	100	220	22	104	
Halifax.....	600		20	80	100	16.66	40	10
Harnett.....	500			40	40	8	15	25
Haywood.....	300	20	2		22	7.33	— 10	150
Henderson.....	500			60	60	12	60	100
Hertford.....	600						— 15	
Hoke.....	200			75	75	37.5	75	25
Hyde.....	300						— 2.5	100
Iredell.....	700	25		240	265	37.85	239	20
Jackson.....	400							20
Johnston.....	900			200	200	22.22	146	20
Jones.....	225			4	4	1.77	4	15
Lee.....	250		36	32	68	27.2	68	
Lenoir.....	500			65	65	13	65	
Lincoln.....	400			100	100	25	100	20
McDowell.....	350	8		36	44	12.57	18	40
Macon.....	750	4		5	9	1.2	9	20
Madison.....	300			10	10	3.33	10	60
Martin.....	400			65	65	16.25	65	10
Mecklenburg.....	1,000	300	4 55	30	385	38.5	152	20
Mitchell.....	500							3
Montgomery.....	400		30	37	67	19.25	67	50
Moore.....	600			230	230	38.33	205	10
Nash.....	800	1	10	115	126	15.75	92	130
New Hanover.....	125	49		5	54	43.22	4	11
Northampton.....	675		12	12	12	1.76	— 8	
Onslow.....	300			5	5	1.66	5	
Orange.....	300	8	4	69	81	27	61	12

¹ Classification not given.² Of which 4 miles were treated with bituminous material.³ Bituminous macadam.⁴ Includes 35 miles for which no classification was given.

NORTH CAROLINA—Continued.

TABLE 46.—*Miles of public roads outside of incorporated cities, 1914—Continued.*

County.	Total mileage of all roads.	Surfaced roads.						Graded and drained earth roads.
		Macadam.	Gravel.	Sand- clay.	Total sur- faced.	Per- centage of total surfaced.	Increase in surfaced mileage over 1909.	
Pamlico.....	200	.....	.....	.....	.....	.....	.....	5
Pasquotank.....	300	.....	.....	.....	.....	.....	.....	.....
Pender.....	500	.....	.....	18	18	3.6	18	.....
Perquimans.....	350	.....	.....	.....	.....	.....	.....	50
Person.....	800	.....	.....	5	5	.62	5	.....
Pitt.....	1,000	.....	.....	50	50	5	48	.....
Polk.....	300	8.5	.....	10	18.5	6.16	15	65
Randolph.....	900	.....	110	.....	110	12.22	106	10
Richmond.....	600	.....	50	200	250	41.66	129	10
Robeson.....	900	.....	.....	100	100	11.11	50	10
Rockingham.....	600	13	.....	13	13	2.16	4	300
Rowan.....	500	75	.....	65	140	28	51	20
Rutherford.....	800	.....	.....	14	14	1.75	14	300
Sampson.....	1,200	.....	.....	165	165	13.75	115	.....
Scotland.....	300	.....	.....	175	175	58.33	120	10
Stanley.....	550	.....	.....	5	5	.90	5	12
Stokes.....	400	.....	.....	75	75	18.75	75	10
Surry.....	350	.....	.....	80	80	22.85	80	15
Swain.....	300	.....	.....	5	5	1.66	5	5
Transylvania.....	250	.....	.....	5	5	2	5	5
Tyrrell.....	200	.....	.....	.....	.....	.....	.....	6
Union.....	900	4	.....	.....	4	.44	— 36	100
Vance.....	300	.....	.....	125	125	41.66	80	.....
Wake.....	1,200	1 2.25	100	100	202.25	16.85	22.25	400
Warren.....	520	.....	.....	15.5	15.5	2.98	— 24.5	.....
Washington.....	300	.....	.....	28	28	9.33	26	50
Watauga.....	300	.....	.....	.....	.....	.....	— 10	10
Wayne.....	1,000	.....	10	200	210	21	180	300
Wilkes.....	1,000	1	.....	.....	1	.10	1	150
Wilson.....	800	24	1	35	60	7.50	30	40
Yadkin.....	300	.....	.....	.....	.....	.....	.....	.....
Yancey.....	80	.....	.....	3	3	3.75	3	17
Total.....	50,758	1,121.25	564	4,318.50	6,003.75	11.82	3,690.75	4,181

¹ Includes 1.25 miles of concrete.

OKLAHOMA.

TABLE 47.—Miles of public roads outside of incorporated cities, 1915.

County.	Total mileage of all roads.	Surfaced roads.						Graded and drained earth roads.
		Macadam.	Gravel.	Sand- clay.	Total sur- faced.	Per- centage surfaced.	Increase in surfaced mileage over 1909.	
Adair.....	475		2		2	0.42	2	3
Alfalfa.....	1,776							
Atoka.....	1,180							6
Beaver.....	3,604							12
Beckham.....	1,440						— 6	38
Blaine.....	1,872			10	10	.53	— 5.5	100
Bryan.....	1,400		4		4	.28	— 26	46
Caddo.....	2,700							100
Canadian.....	1,800						— 3	
Carter.....	1,493							60
Cherokee.....	800							
Choctaw.....	700							
Cimarron.....	1,000							
Cleveland.....	1,050							300
Coal.....	900							5
Comanche.....	1,812						— 4	5
Cotton.....	1,307							100
Craig.....	1,552							
Creek.....	1,400							10
Custer.....	1,520							10
Delaware.....	960							38
Dewey.....	1,500							
Ellis.....	2,525			5	5	.19	5	200
Garfield.....	2,000							109
Garvin.....	1,600							200
Grady.....	2,200							64
Grant.....	2,016						— 10	50
Greer.....	1,000						— 5	4
Harmon.....	800			20	20	2.5	20	80
Harper.....	2,020							
Haskell.....	900							20
Hughes.....	1,375							11
Jackson.....	1,552						— 25	25
Jefferson.....	533							
Johnston.....	700							20
Kay.....	1,654							65
Kingfisher.....	1,845							
Kiowa.....	2,100							500
Latimer.....	295							
Le Flore.....	1,000							
Lincoln.....	2,080			5	5	.24	— 34.50	50
Logan.....	1,512			4	4	.26	4	46
Love.....	600							
McClain.....	(¹)						— 2	
McCurtain.....	1,305							
McIntosh.....	1,440							
Major.....	1,942						— 10	6
Marshall.....	510							48
Mayes.....	1,368							22
Murray.....	550							15
Muskogee.....	1,870						— 25	75
Noble.....	1,494							25
Nowata.....	1,130							32
Okfuskee.....	800							90
Oklahoma.....	1,500			10	10	166	10	20
Oklmulgee.....	1,400							100
Osage.....	2,500							
Ottawa.....	750		0.9		.9	.12	— 3.10	
Pawnee.....	1,160			1	1.0	.08	1	
Payne.....	1,420							60
Pittsburg.....	650						— 123	23
Pontotoc.....	840							20
Pottawatomie.....	1,500						— 50	
Pushmataha.....	640							
Roger Mills.....	615							2
Rogers.....	1,800							40
Seminole.....	800							
Sequoyah.....	637							20
Stephens.....	1,400							
Texas.....	4,046						— 4	38
Tillman.....	1,600							
Tulsa.....	1,400	² 9.70			9.7	.65	4.7	170
Wagoner.....	1,110							

¹ No report.² Includes 3 miles of bituminous macadam.

OKLAHOMA—Continued.

TABLE 47.—Miles of public roads outside of incorporated cities, 1914—Continued.

County.	Total mileage of all roads.	Surfaced roads.						Graded and drained earth roads.
		Macadam.	Gravel.	Sand-clay.	Total surfaced.	Percentage surfaced.	Increase in surfaced mileage over 1909.	
Washington.....	553	.....	.....	.....	.....	.....	.....	23
Washita.....	1,612	.....	.....	.....	.....	.....	.....	.....
Woods.....	2,500	.....	.....	.....	.....	.....	.....	.....
Woodward.....	2,526	.....	.....	50	50	1.97	50	.....
Total.....	107,916	9.70	6.9	105	121.6	.11	-239.4	3,106

SOUTH CAROLINA.

TABLE 48.—Miles of public roads outside of incorporated cities, 1914.

County.	Total mileage of all roads.	Surfaced roads.					Graded and drained earth roads.
		Sand-clay.	Other hard surfaced roads.	Total surfaced.	Percentage of total surfaced.	Increase in surfaced mileage over 1909.	
Abbeville.....	1,200	75	.....	75	6.25	-226	500
Aiken.....	1,280	350	.....	350	27.40	100	300
Anderson.....	1,208	500	.....	500	41.39	490	.....
Bamberg.....	400	125	.....	125	31.25	.....	.....
Barnwell.....	1,000	150	.....	150	15	-35	350
Beaufort.....	480	.....	2 40	40	8.33	25	.....
Berkeley.....	1,500	.....	.....	.....	.....	-10	225
Calhoun.....	300	100	.....	100	33.33	.....	.....
Charleston.....	500	40	{ 3 30 2 8 }	78	15.60	64	122
Cherokee.....	1,422	.....	.....	.....	.....	-3	300
Chester.....	680	50	4 15	65	9.55	45	100
Chesterfield.....	1,200	36	.....	36	3	26	137
Clarendon.....	800	50	.....	50	6.25	50	350
Colleton.....	1,005	66	.....	66	6.56	66	139
Darlington.....	1,000	200	.....	200	20	-150	550
Dillon.....	625	25	.....	25	4	25	100
Dorchester.....	800	.....	.....	.....	.....	-200	300
Edgefield.....	835	15	.....	15	1.79	15	150
Fairfield.....	650	50	.....	50	7.69	50	300
Florence.....	1,150	200	2 25	225	19.56	193	650
Georgetown.....	479	60	2 5 5	65.5	13.68	8.5	150
Greenville.....	2,004	.....	{ 4 3 5 1.5 }	4.5	.22	-2.5	200
Greenwood.....	2,000	.....	.....	.....	.....	-38	.....
Hampton.....	1,202	2	.....	2	.16	-248	700
Horry.....	2,000	10	.....	10	.50	6	150
Jasper.....	700	.....	.....	.....	.....	.....	50
Kershaw.....	650	137	2 18	155	23.84	32	160
Lancaster.....	600	30	.....	30	5	-5	125
Laurens.....	1,470	20	.....	20	1.36	-69	350
Lee.....	400	100	.....	100	25	69	150
Lexington.....	1,555	105	.....	105	6.75	15	350
Marion.....	480	85	.....	85	17.70	85	35
Marlboro.....	580	30	.....	30	5.17	-32	100
Newberry.....	1,000	36	2 12	48	4.80	27	200
Oconee.....	1,400	.....	.....	.....	.....	.....	.....
Orangeburg.....	1,600	50	.....	50	3.12	-325	550
Pickens.....	600	.....	4 1	1	.16	.....	.....
Richland.....	752	200	5 2	202	26.86	-248.5	400
Saluda.....	614	14	.....	14	2.28	4	250
Spartanburg.....	1,700	.....	.....	.....	5.88	-14	1,000
Sumter.....	525	100	.....	100	19.05	25	285
Union.....	565	5	6 8.5	13.5	2.38	5	250
Williamsburg.....	1,455	25	.....	25	1.71	-5	1,086
York.....	860	60	.....	60	6.97	-78.75	500
Total.....	42,226	3,101	169.50	3,270.5	7.74	-264.25	11,614

¹ Scaled from soil survey map.³ Gravel.⁵ Bituminous macadam.² Shell.⁴ Macadam.⁶ Poor macadam.

TENNESSEE.

TABLE 49.—Miles of public roads outside of incorporated cities, 1914.

Counties.	Total mileage of all roads.	Surfaced roads.						Graded and drained earth roads.
		Macadam.	Gravel.	Sand-clay.	Total surfaced.	Percentage of total surfaced.	Increase in surfaced mileage over 1909.	
Anderson.....	285	75	10		85	29.82	11	
Bedford.....	200						-125	31
Benton.....	¹ 430		150		150	34.88	135	40
Bledsoe.....	350	30	30		60	17.14	50	75
Blount.....	¹ 550	55			55	10	42	
Bradley.....	345		190		190	55.07	10	80
Campbell.....	665	45	20		65	9.77	10	
Cannon.....	500	10	10		20	4	13	
Carroll.....	¹ 250							100
Carter.....	200	20			20	10	20	180
Cheatham.....	500	14	34	50	98	19.60	84	150
Chester.....	260							
Claiborne.....	300	10			10	3.33	5	130
Clay.....	200						-5	
Cocke.....	400	80			80	20		
Coffee.....	¹ 375							60
Crockett.....	500							300
Cumberland.....	200							20
Davidson.....	600	275	100		375	62.5	133	125
Decatur.....	506		6		6	1.18	-37.5	
Dekalb.....	500	40			40	8	-35	
Dickson.....	283	54	4		58	20.49	54	25
Dyer.....	201		11.5		11.5	5.7	-8.5	100
Fayette.....	900							600
Fentress.....	350							50
Franklin.....	405	5			5	1.23	3	100
Gibson.....	¹ 1,000							200
Giles.....	¹ 1,000						-175	500
Grainger.....	300	8			8	2.66	3	23
Greene.....	¹ 532	160			160	10.44	159	172
Grundy.....	300							
Hamblen.....	300	100			100	33.33	4	
Hamilton.....	495	² 19.5	200		219.5	44.38	74.5	150
Hancock.....	250							
Hardeman.....	750		3		3	.4		
Hardin.....	410		80		80	19.51	60	80
Hawkins.....	375	14			14	3.73	-12	90
Haywood.....	800		3.5		3.5	.43	-3.5	200
Henderson.....	400							
Henry.....	¹ 1,000	20	5		25	2.5	21.5	100
Hickman.....	750							
Houston.....	150						-5	
Humphreys.....	600		125	40	165	27.5	165	40
Jackson.....	325	35	95		130	40	130	
James.....	110		2		2	1.81	-28	4
Jefferson.....	558	160			160	28.67	57	38
Johnson.....	150							
Knox.....	¹ 1,000	³ 375			375	37.5	126	225
Lake.....	115	1			1	.86	1	50
Lauderdale.....	600			100	100	16.66	91	75
Lawrence.....	300		100		100	33.33	60	100
Lewis.....	200		8	25	33	16.5	13	25
Lincoln.....	800		80		80	10	-73	
Loudon.....	368	21.5	25		46.5	12.63	46.5	61.5
McMinn.....	600	40	5		45	7.5	14.5	150
McNairy.....	300		12		12	4	12	45
Macon.....	348		26		26	7.47	26	10
Madison.....	714		⁴ 131	3	134	18.76	-58	150
Marion.....	230	75		25	100	43.47	60	30
Marshall.....	556	200	150		350	62.94	205	100
Maury.....	¹ 1,125	150	225	250	625	55.55	299	250
Meigs.....	200		10		10	5	7	10
Monroe.....	320						-10	120
Montgomery.....	650	90	60		150	23.07	24	
Moore.....	85		15	10	25	29.41	15	10
Morgan.....	375							300
Obion.....	¹ 1,000							
Overton.....	220							

¹ 1909 total.² Includes 5 miles of bituminous macadam, 2 miles of concrete, and $\frac{1}{2}$ mile of brick,³ Includes 75 miles of bituminous macadam.⁴ Includes 66 miles of gravel treated with bituminous material.

TENNESSEE—Continued.

TABLE 49.—Miles of public roads outside of incorporated cities, 1914—Continued.

Counties.	Total mileage of all roads.	Surfaced roads.					Graded and drained earth roads.
		Macadam.	Gravel.	Sand-clay.	Total surfaced.	Percentage of total surfaced.	Increase in surfaced mileage over 1909.
Perry.....	601		50		50	8.31	50
Pickett.....	129						
Polk.....	320	20			20	6.25	20
Putnam.....	340	70	10		80	23.52	2
Rhea.....	342	5	11		16	4.67	
Roane.....	550	45	8		53	9.63	
Robertson.....	630	124	20		144	22.85	144
Rutherford.....	1,100	700			700	63.63	250
Scott.....	100						— 9
Sequatchie.....	150						— 12
Sevier.....	600	30			30	5	— 1
Shelby.....	1,352	1 652	100		752	55.62	152
Smith.....	450	15	395		410	91.11	220
Stewart.....	550	2	3		5	.9	— 21
Sullivan.....	650	125			125	19.23	50
Sumner.....	750	70	50		120	16	—230
Tipton.....	750						500
Trousdale.....	165	30	40		70	42.42	50
Unicoi.....	75						
Union.....	235	35			35	14.89	
Van Buren.....	250	16			16	6.4	16
Warren.....	385	60			60	15.58	— 12
Washington.....	500	50			50	10	47
Wayne.....	420		50	10	60	14.28	44
Weakley.....	350						200
White.....	210	70			70	33.33	— 50
Williamson.....	630	100	125	100	325	51.58	210
Wilson.....	550	300			300	54.54	160
Total.....	46,050	4,701	2,788	613	8,102	17.59	2,748.5

¹ Includes 2 miles of bituminous concrete.

NOTE.—The above information was compiled partly from cards received from county road officials and partly from a summary sheet furnished by Mr. J. J. Murray, secretary of the State road commission and United States collaborator.

TEXAS.

TABLE 50.—*Miles of public roads outside of incorporated cities, 1914.*

Counties.	Total mileage of all roads.	Surfaced roads.						Graded and drained earth roads.	
		Macadam.	Gravel.	Sand-clay.	Other hard surfaced.	Total surfaced.	Percentage of total surfaced.		Increase in surfaced mileage over 1909.
Anderson.....	652		7	45		52	7.97	32	300
Andrews.....	275								
Angelina.....	200								
Aransas.....	100			45		45	45	35	25
Archer.....	1,500			400		400	26.66	400	100
Armstrong.....	149							— 15	75
Atascosa.....	200			50		50	25	— 10	50
Austin.....	500			100		100	20	95	125
Bailey.....	165								
Bandera.....	200								
Bastrop.....	1,405		80	25		105	7.47	80	1,000
Baylor.....	192			12		12	6.25	11.75	90
Bee.....	500							— 5	173
Bell.....	2,000								
Bexar.....	1,032		357.68	43.58	1 13	414.26	40.15	214.26	
Blanco.....	365								
Borden.....	170								
Bosque.....	800		190	10		200	25	185	400
Bowie.....	1,000		42			42	4.2	2	250
Brazoria.....	600		25		2 20	45	7.5	45	100
Brazos.....	600							— 5	200
Brewster.....	292								142
Briscoe.....	140								40
Brooks.....	160			18		18	11.25	18	
Brown.....	400	75	3			78	19.5	48	
Burleson.....	350			25		25	7.14	15	50
Burnet.....	840								198
Caldwell.....	328		100	3		103	31.4	89	25
Calhoun.....	305		30.5		2 45	75.5	24.71	75.5	105
Callahan.....	600		10	75	3 15	100	16.66	60	400
Cameron.....	650								350
Camp.....	300								
Carson.....	77								25
Cass.....	1,000			15		15	1.5	15	85
Castro.....	170								12
Chambers.....	175			10	2 25	35	20	30	130
Cherokee.....	500							— 70	200
Childress.....	300								
Clay.....	1,000							— 5	500
Cochran.....	150								
Coke.....	300								75
Coleman.....	600								200
Collin.....	678	125			4 3	128	18.87	125.5	550
Collingsworth.....	620		250	35		285	45.96	285	85
Colorado.....	1,170		10	10		20	1.7	20	50
Comal.....	290	20	70			90	31.03	— 10	50
Comanche.....	1,275							—105	575
Concho.....	150								50
Cooke.....	310		25			25	8.06	15	185
Coryell.....	925		25			25	2.7	25	400
Cottle.....	300								
Crane.....	100								
Crockett.....	200								30
Crosby.....	415								15
Culberson.....	500								100
Dallam.....	195			20		20	10.25	19	100
Dallas.....	1,300	10	500	2	5 10	522	40.15	304	400
Dawson.....	100								
Deaf Smith.....	200							— 20	100
Delta.....	450								150
Denton.....	1,000	42	3		6 3	48	4.8	33	100
De Witt.....	1,000							— 95	30
Dickens.....	175								60
Dimmit.....	450			50		50	11.11	30	200
Donley.....	275			200		200	72.72	180	25
Duval.....	150								
Eastland.....	200			55		55	27.5	5	40
Ector.....	70								
Edwards.....	425								
Ellis.....	2,000		400			400	20	269.5	

¹ Bituminous gravel.

² Shell.

³ Cinder.

⁴ Concrete.

⁵ Bituminous macadam.

TEXAS—Continued.

TABLE 50.—Miles of public roads outside of incorporated cities, 1914—Continued.

Counties.	Total mileage of all roads.	Surfaced roads.							Graded and drained earth roads.
		Macadam.	Gravel.	Sand-clay.	Other hard surfaced.	Total surfaced.	Percentage of total surfaced.	Increase in surfaced mileage over 1909.	
El Paso.....	310	70	32			102	32.9	43.5	
Erath.....	1,200	.50	.50	100	¹ 30	131	10.91	70	100
Falls.....	312		6	6		12	3.84	— 38	200
Fannin.....	1,500								
Fayette.....	1,050		90	20		110	10.47	10	150
Fisher.....	500								20
Floyd.....	1,150								500
Foard.....	116			1.5		1.5	1.28	1.5	40
Fort Bend.....	500		35		² 17	52	10.4	29	348
Franklin.....	500		35			35	7	35	40
Freestone.....	1,000								
Frio.....	250			150		150	60	125	
Gaines.....	115							— 1	40
Galveston.....	215				² 124.85	124.85	58.11	113.85	60
Garza.....	455								125
Gillespie.....	550		25	100		125	22.7	108	150
Glasscock.....	100								30
Goliad.....	376		10	12		22	5.8	19	152
Gonzales.....	1,000		43			43	4.3	— 2	300
Gray.....	200								
Grayson.....	2,120	40	80			120	5.66	119.75	
Gregg.....	231	2	50	50	³ 4	106	45.88	106	50
Grimes.....	245	20	25	50		95	38.77	95	
Guadalupe.....	700							—223	
Hale.....	516							— 5	212
Hall.....	233			8		8	3.43	8	100
Hamilton.....	350							— 30	50
Hansford.....	50								
Hardeman.....	1,000			10		10	1	10	290
Hardin.....	225			5	² 25	30	13.33	20	185
Harris.....	1,311		69.8	40	² 285.6	395.4	30.22	130.4	200
Harrison.....	412	2		60		62	15.04	—101	200
Hartley.....	300								200
Haskell.....	510			10		10	1.96	10	100
Hays.....	500		40			40	8		10
Hemphill.....	160							— 7	75
Henderson.....	1,500								
Hidalgo.....	1,045								245
Hill.....	2,000		21	6	³ 5	32	1.6	24	768
Hockley.....	60								
Hood.....	150		50			50	33.33	50	50
Hopkins.....	900								100
Houston.....	140			70		70	50	60	20
Howard.....	133		23	110		133	100	123	
Hunt.....	1,600								
Hutchinson.....	26			2		2	7.69	2	
Irion.....	162		5	42		47	29.01	47	35
Jack.....	700	4		15		19	2.71	— 86	200
Jackson.....	500							—120	
Jasper.....	260			10		10	3.84	10	120
Jeff Davis.....	250								40
Jefferson.....	513			.50	² 110 ³ 2	112.5	21.95	27.5	300
Jim Hogg.....	40								
Jim Wells.....	250								150
Johnson.....	1,400		100	50		150	10.71	115	
Jones.....	1,000			41		41	4.10	31	400
Karnes.....	400							— 3	200
Kaufman.....	1,600		65	6	⁴ 2	73	4.56	71	75
Kendall.....	285		2		¹ 5	7	2.46	7	
Kent.....	250								100
Kerr.....	400		100			100	25	83	200
Kimble.....	155								25
King.....	80								
Kinney.....	197								197
Kleberg.....	211			16		16	7.58	16	120
Knox.....	1,000								
La Salle.....	250		1	40		41	16.4	41	159
Lamar.....	1,240		40			40	3.22	36	200
Lamb.....	7								

¹ Not classified as to type.² Shell.³ Bituminous macadam.⁴ Concrete.

TEXAS—Continued.

TABLE 50.—Miles of public roads outside of incorporated cities, 1914—Continued.

Counties.	Total mileage of all roads.	Surfaced roads.						Graded and drained earth roads.
		Macadam.	Gravel.	Sand-clay.	Other hard surfaced.	Total surfaced.	Percentage of total surfaced.	
Lampasas.	400							
Lavaca.	800			100		100	12.5	300
Lee.	1,100							
Leon.	70							15
Liberty.	326				¹ 46	46	14.11	200
Limestone.	800							
Lipscomb.	150							
Live Oak.	355	2		3		5	1.4	50
Llano.	488							
Loving ² .								
Lubbock.	280							30
Lynn.	190							
McCulloch.	350							50
McLennan.	1,576		200		³ 6 ⁴ 70	276	17.51	1,000
McMullen.	123							78
Madison.	515							22
Marion.	300			25		25	6.33	50
Martin.	75			5		5	6.66	5
Mason.	292							100
Matagorda.	355		3	2	¹ 10	15	4.22	15
Maverick.	195	25	20			45	23.07	45
Medina.	780	10	10	20		40	5.12	35
Menard.	230		10	40	⁵ 100	150	65.21	150
Midland.	100			50		50	50	50
Milam.	1,650		62	100		162	9.81	127
Mills.	500							200
Mitchell.	275							275
Montague.	900		20			20	2.22	20
Montgomery.	900		80	20		100	11.11	200
Moore.	50							
Morris.	360							160
Motley.	135			5		5	3.7	5
Nacogdoches.	902			27		27	2.99	15
Navarro.	2,000		90			90	4.5	90
Newton.	400							200
Nolan.	533	6	22	5		33	6.19	33
Nueces.	560		26.50	6.9	⁴ 1.13	34.53	7.77	14.53
Ochiltree.	145							35
Oldham.	200							
Orange.	200		7		¹ 18	25	12.5	10
Palo Pinto.	288	12.5	13		⁶ 3	28.5	9.87	28.5
Panola.	1,000							20
Parker.	1,800		300			300	16.66	300
Parmer.	255							40
Pecos.	750							15
Polk.	600							
Potter.	300							100
Presidio.	215	20		20	⁵ 50	90	41.86	65
Raines.	285							
Randall.	450							300
Reagan.	165							
Real.	125				⁵ .5	.5	.01	.50
Red River.	950							200
Reeves.	190							65
Refugio.	200							150
Roberts.	70							10
Robertson.	450		150	30		180	40	180
Rockwall.	210							130
Runnels.	450							
Rusk.	950							
Sabine.	350							120
San Augustine.	550							
San Jacinto.	330							15
San Patricio.	136							36
San Saba.	745		25	20	⁴ 11	56	7.51	56

¹ Shell.² No report for this county in 1904, 1909, or 1914, as it is but sparsely settled.³ Concrete.⁴ Bituminous macadam.⁵ Not classified as to type.⁶ Cinder.

TEXAS—Continued.

TABLE 50.—Miles of public roads outside of incorporated cities, 1914—Continued.

Counties.	Total mileage of all roads.	Surfaced roads.						Graded and drained earth roads.	
		Macadam.	Gravel.	Sand- clay.	Other hard surfaced.	Total surfaced.	Percent- age of total surfaced.		Increase in surfaced mileage over 1909.
Schleicher	230								30
Scurry	400							— 10	200
Schackelford	241							— .5	50
Shelby	1,000								
Sherman	150								
Smith	650			200		200	30.76	180	50
Somervell	165		15	40		55	33.15	60	50
Starr	173		2			2	1.15	— 73	
Stephens	388			1.5		1.5	.38	.5	63
Sterling	124								40
Stonewall	175			15		15	8.57	3	20
Sutton	200								
Swisher	261								61
Tarrant	1,086	6.5	500	5	175	586.5	53.98	256.5	200
Taylor	453	8	40	5		53	11.25	43	200
Terrell	150								150
Terry	240			20		20	8.33	15	
Throckmorton	175								
Titus	450							— 10	50
Tom Green	300								250
Travis	1,150	4	75	20	$\left\{ \begin{smallmatrix} 214 \\ 3.25 \end{smallmatrix} \right\}$	113.25	9.84	— 61.75	354
Trinity	294			34		34	11.56	34	10
Tyler	160							— 25	
Upshur	600							— 3	40
Upton	104								44
Uvalde	405		5			5	1.23	5	150
Val Verde	260	2.5	2			4.5	1.73	— 70.5	5
Van Zandt	1,230		10	45		55	4.46	55	175
Victoria	795		145			145	18.23	128	350
Walker	420			55		55	13.09	44	20
Waller	319		4	35		39	12.22	39	230
Ward	181	4		2		6	3.31	6	25
Washington	600								300
Webb	300		50	25		75	25	— 50	35
Wharton	806		6			6	.74	5	800
Wheeler	175								
Wichita	975							— 3	355
Wilbarger	800			70		70	8.75	66	200
Willacy	72			9.5		9.5	13.28	9.5	
Williamson	1,505		255			255	16.94	192	1,050
Wilson	600				100	100	10	100	
Winkler	125								
Wise	1,700		35			35	2.05	— 15	
Wood	500			150		150	30	142	300
Yoakum	73				16	16	21.91	16	17
Young	1,015							—156	215
Zapata	60								
Zavalla	220							— 1	20
Total....	128,960	511.00	5,258.98	3,490.48	1,265.33	10,526.79	8.16	5,640.79	29,866

¹ Bituminous macadam.² Shell.³ Concrete.⁴ Not classified as to type.

VIRGINIA.

TABLE 51.—Miles of all public roads, State and local, outside of incorporated cities, 1914.

County.	Total mileage, all roads.	Surfaced roads.						Graded and drained earth mileage roads.		
		Macadam	Bituminous macadam.	Gravel.	Sand-clay.	Other hard surfaced roads.	Total surfaced.		Per cent of total surfaced.	Increase in surfaced road mileage over 1909.
Accomac.....	1 550	4.47			2 79.87	10.28 shell.	94.62	17.2	89.37	.....
Albemarle.....	914	8.7	4.7			9 cinders, 0.5 concrete, 1 Belgian block.	13.4	1.46	5.15	200
Alexandria.....	101	31	7.4	24.5		15 slag surfaced.	73.4	72.52	42.4	24
Alleghany.....	350				2 27		15	4.28	27	100
Amelia.....	500	42			2		27	5.4	22	.....
Amherst.....	600				9		44	7.33	6	.....
Appomattox.....	500						9	1.8	6	250
Augusta.....	1,997	30	67				97	4.85	36.5	100
Bath.....	326	10.5					10.5	3.22	3.5	400
Bedford.....	775	9			2	10 old railroad ballast.	21	2.7	14.5	25
Bland.....	525						8	1.33	8	10
Botetourt.....	600	8		20	75		95	13.85	90	6
Brunswick.....	685									.....
Buchanan.....	331				2 9		9	1.28	9	200
Buckingham.....	700					.25 rough rubble paved.	9.25	1.64	1.75	110
Campbell.....	562	5.5	3.5	65			65	9.28	50	2
Caroline.....	700									.....
Carroll.....	1,070			6.33	5.06		11.39	4.74	10.61	.....
Charles City.....	240	6			100		106	11.77	101	.....
Charlotte.....	900				2.5		202.5	33.75	102.5	50
Chesterfield.....	600		200				40.5	12.98	.5	.....
Clarke.....	312	40.5								.....
Craig.....	225									.....
Culpeper.....	500	40.9					40.9	8.18	27.4	37
Cumberland.....	150				13		13	8.66	12.75	41
Dickenson.....	604								10	68
Dinwiddie.....	600		52		2 72		124	20.66	4	40
Elizabeth City.....	80		3.5			.5 brick and 36 shell.	40	50	6	40
Essex.....	200			5	21		26	13	24	.....
Fairfax.....	620	10.25	2.5	30			42.75	6.89	2.25	.....
Fauquier.....	879	9	20				29	3.29	18.5	.....
Floyd.....	800								10	100
Fluvanna.....	200									.....
Franklin.....	1,500					10.	10	.66	10	.....
Frederick.....	700	7	3 46				53	7.57	25	92

VIRGINIA—Continued.

TABLE 51.—*Miles of all roads, State and local, outside of incorporated cities, 1914—Continued.*

County.	Total mileage, all roads.	Surfaced roads.						Graded and drained earth roads.		
		Macadam	Bituminous macadam.	Gravel.	Sand-clay.	Other hard surfaced roads.	Total surfaced.		Per cent of total surfaced.	Increase in surfaced road mileage over 1909.
Scott.....	780	18.5	36				54.5	4.7	11.5	63
Shenandoah.....	1,158	40.55					40.55	10.55	10.55	48
Smyth.....	384				55		55	8.39	48	
Southampton.....	655			49	11		61.7	13.05	61.7	
Spotsylvania.....	452	1.7		36			36	12.16	33	
Stafford.....	296				8		8	2.66	4	
Surry.....	300				5		5	.41	1	100
Sussex.....	1,200									45
Tazewell.....	515	88.8	.6				89.4	1.73	67.9	73
Warren.....	315	10.5					10.5	3.33	2.5	304
Warwick.....	87			3	3	9 shell.	15	17.24	9	70
Washington.....	475	55					55	11.57	15	20
Westmoreland.....	221			30	40		70	3.16	61.25	
Wise.....	279	35	37		1		73	26.16	59	68
Wythe.....	1,700	62					62	8.85	8	
York.....	132				15		15	11.36	15	59
Total.....	53,388	1,177.89	255.77	822.09	1,511.65		3,909.57	7.32	2,006.82	4,977

¹ From 1909 report; the total mileage figures for 1914 not obtainable.

WEST VIRGINIA.

TABLE 52.—Miles of all public roads, State and local, outside of incorporated cities, 1914.

County.	Total mile- age, all roads.	Surfaced roads.							Graded and drained earth roads.	
		Mac- adam, plain.	Bitu- minous mac- adam.	Brick, paved.	Con- crete.	Gravel.	Total sur- faced.	Per- cent- age of total sur- faced.		In- crease in sur- faced road mileage over 1909.
Barbour.....	624			4			4	.6	4	130
Berkeley.....	456	97				1 48	145	31.8	80	110
Boone.....	575									45
Braxton.....	780									80
Brooke.....	175	50		2			52	29.2	36	100
Cabell.....	400		1	18			19	4.75	16.5	100
Calhoun.....	500									50
Clay.....	450									
Doddridge.....	800									100
Fayette.....	933	9	6				15	1.6	12.5	53
Gilmer.....	650	.12					.12	.018	—13	50
Grant.....	311									50
Greenbrier.....	827	8					8	.96	8	60
Hampshire.....	950									
Hancock.....	184	.80		15			15.8	7.6	15.8	68
Hardy.....	320									
Harrison.....	700	5.50	11.25	4			20.75	2.9	10.75	250
Jackson.....	1,200									450
Jefferson.....	340	280					280	82.4	112	40
Kanawha.....	830			3			3	.36	1	100
Lewis.....	752	1.50		.50			2	.26	2	100
Lincoln.....	665	4					4	.6	4	61
Logan.....	200			4			4	2	4	46
McDowell.....	445	10					10	2.2	3	35
Marion.....	650		9.70	14	5	2	30.7	4.7	28.2	275
Marshall.....	700	40		11		10	61	8.7	—12	250
Mason.....	900									100
Mercer.....	402	15	27				42	10.4	39.6	260
Mineral.....	300									50
Mingo.....	200	2		4			6	3	6	42
Monongahela.....	800	1	1	1.10			3.1	.38	—36.9	203
Monroe.....	600	8					8	1.3	8	100
Morgan.....	325	1					1	.03	1	
Nicholas.....	516	25					25	4.8	25	
Ohio.....	280	177	7	20			204	80.0	49	76
Pendleton.....	250									
Pleasants.....	290				5.50	.50	6	2.07	6	30
Pocahontas.....	500	14				2 30	44	8.8	40	95
Preston.....	1,200			2			2	.16	2	400
Putnam.....	570									16
Raleigh.....	616									16
Randolph.....	1,000									150
Ritchie.....	900									75
Roane.....	700			2	2		4	.57	4	76
Summers.....	485									85
Taylor.....	366	8		3			11	.3	8	150
Tucker.....	400									100
Tyler.....	520	5		.25			5.25	1.01	—1	100
Upshur.....	800									50
Wayne.....	700			3			3	.42	3	100
Webster.....	338									38
Wetzel.....	630			.25			.25	.03	—25.75	300
Wirt.....	490									90
Wood.....	1,029	10		10	6		26	2.5	20	303
Wyoming.....	500									
Total.....	32,024	771.92	62.95	121.10	18.50	90.50	1,064.97	3.3	473.57	5,705

¹ Includes 40 miles of shale.² Shale.

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UNITED STATES DEPARTMENT OF AGRICULTURE



BULLETIN No. 388

Contribution from the Office of Public Roads and
Rural Engineering

LOGAN WALLER PAGE, Director



Washington, D. C.



January 8, 1917

PUBLIC ROAD MILEAGE AND REVENUES IN THE NEW ENGLAND STATES, 1914.

A Compilation Showing Mileage of Improved and Unimproved Roads, Sources and Amounts of Road Revenues, Bonds Issued and Outstanding, and a Description of the Systems of Road Administration, Fiscal Management, and Other Factors Affecting Road Improvement in Each State.

Prepared Jointly by the Division of Road Economics, of the Office of Public Roads and Rural Engineering, and State Collaborators.

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INTRODUCTORY.

Beginning with 1904, the policy of conducting at five-year intervals an investigation to determine the mileage of improved and unimproved roads, the revenues for road purposes, and related data, was adopted by the Office of Public Roads. In accordance with that policy Bulletin No. 32 was issued, giving such information as was obtainable for the calendar year 1904, and Bulletin No. 41 was issued, giving such information as was available for the calendar year 1909. The investigation made for the year 1914 followed somewhat different lines, as a closer cooperation with State highway departments was maintained, and wherever practicable the information was collected directly by collaborators named by the respective State highway departments and acting under specific instruction from this office. This policy was not practicable in connection with earlier bulletins, owing to the fact that many of the States have only recently established highway departments. The collaborators for the New England

States, who furnished valuable assistance in compiling the information for this bulletin, are as follows: For Maine, Lucius D. Barrows; for New Hampshire, Frank W. Brown; for Vermont, M. E. Shedd; for Rhode Island, Peter J. Lannon; for Connecticut, C. G. Nichols; and for Massachusetts, W. D. Sohier and T. N. Waddell. Similar bulletins have been prepared for publication for the Middle Atlantic States, the Southern States, and for the Middle Western and Western States.

WORKING PLAN AND SOURCES OF INFORMATION.

The method pursued in obtaining the information contained in this bulletin was as follows:

A series of card inquiry forms covering conditions in each State and designated A, B, C, and D, covering, respectively, mileage, taxation and revenues, administrative organization, and bond issues, was furnished to each State collaborator, and correspondence was then conducted by the collaborators under Government frank with the respective county and town officials. On account of the absence of detailed records in many of the towns, extreme accuracy is impossible, and because of the large amount of correspondence necessary to conduct the investigation considerable delay in the issuance of this bulletin has been unavoidable. The data on mileage and revenues should, therefore, be considered as approximate only. A summary sheet of each of the forms A, B, C, and D was prepared for each State as fast as the card forms were received from the State collaborators. These summaries, when completed, were forwarded to the respective State collaborators and to the heads of the State highway departments, who then prepared texts explanatory of the statistical tables and of the administrative systems in effect in their respective States, or approved the texts prepared in this office. The bulletin is issued, therefore, in the form of a series of chapters, each under the authorship or approval of the State official who has cooperated with this office in assembling the data.

ROAD ADMINISTRATION IN THE NEW ENGLAND STATES.

All of the New England States have highway departments and apply State funds to the aid of road improvement. This policy was inaugurated in Massachusetts in 1892, Connecticut in 1895, Vermont in 1898, Maine in 1901, Rhode Island in 1902, and New Hampshire in 1903. In Vermont the State aid law was enacted in 1898, but the State highway department was not established until 1906. Maine, Rhode Island, and Connecticut have trunk-line systems of roads built entirely at the expense of the State. Massachusetts, New Hampshire, and Vermont have trunk-line systems of roads built by the State, but the towns contribute toward the cost of their construction and maintenance.

Local road and bridge work, exclusive of State and State-aid work, is done by the towns through the town boards of selectmen in all of the New England States, the towns being political subdivisions of the counties. In a few cases, however, where the towns fail to construct or maintain the roads properly, the work is done by the county officials.

Detailed information as to the administration of public roads in each of the New England States is given in the chapters which relate respectively to the several States.

PUBLIC ROAD REVENUES.

The total revenues applied to roads and bridges in the New England States in 1914 amounted to \$15,435,746.01, including State appropriations, amounts derived from local taxation, and expenditures from bond issues, both State and local. In 1904 the total revenues applied to this purpose amounted to \$7,383,755.70, showing an increase in the 10-year period, 1905-1914, inclusive, of \$8,051,990.31, or 104.6 per cent. Table 1 presents in condensed form the information assembled concerning revenues for the New England States for the year 1914, with comparative information for the year 1904.

TABLE 1.—*Revenues applied to roads and bridges, 1914 and 1904.*

State.	Total revenues applied to roads and bridges.		Increase in revenues over 1904.	
	1914	1904	Total increase.	Percentage of increase.
Maine.....	\$2,642,006.79	\$1,472,393.70	\$1,169,613.09	79.43
New Hampshire.....	1,590,464.11	872,606.35	717,857.76	82.2
Vermont.....	1,023,941.01	567,397.33	456,543.68	80.46
Massachusetts.....	6,091,875.30	2,871,222.47	3,220,652.83	112.2
Rhode Island.....	446,496.05	405,010.85	41,485.20	10.2
Connecticut.....	3,640,962.75	1,195,125.00	2,445,837.75	204.6
Total.....	15,435,746.01	7,383,755.70	8,051,990.31	104.6

A comparison showing the average revenues for roads and bridges in the New England States per mile of road, per square mile of area, per capita, and per \$100 of assessed valuation for the years 1904 and 1914 is presented in Table 2. This average does not indicate, however, the distribution of expenditures as between construction and maintenance.

TABLE 2.—*Relation of public road and bridge revenues to mileage, area, population, and assessed valuation, 1914 and 1904.*

State.	Revenues.							
	Per mile of road.		Per square mile of land area.		Per capita.		Per \$100 of assessed value.	
	1914	1904	1914	1904	1914	1904	1914	1904
Maine.....	\$112.25	\$57.68	\$88.37	\$49.29	\$3.55	\$2.12	\$0.633	\$0.418
New Hampshire.....	113.44	57.72	176.11	96.62	3.69	2.12	.362	.427
Vermont.....	71.86	39.07	112.22	62.19	2.87	1.65	.462	.348
Massachusetts.....	326.08	167.99	758.00	357.40	1.81	1.02	.127	.092
Rhode Island.....	205.76	171.54	418.50	379.70	.82	.95	.072	.096
Connecticut.....	258.90	84.84	755.50	248.10	3.26	1.32	.350	.180
Weighted average.....	177.99	83.24	249.06	119.10	2.35	1.32	.204	.150

ROAD AND BRIDGE BONDS.

The total town and State highway road and bridge bonds outstanding on January 1, 1915, in the New England States, amounted to \$20,565,522.82. Town bonds were issued in Massachusetts only and amounted to \$1,606,022.82. Information in regard to bond issues by States is presented in Table 3. Detailed information showing bonds issued by towns in Massachusetts is shown in the chapter for that State.

TABLE 3.—*Road and bridge bonds outstanding.*

State.	Town bonds outstanding Jan. 1, 1915.	State highway bonds outstanding Jan. 1, 1915.
Maine.....		\$785,000.00
New Hampshire.....		675,000.00
Vermont.....		
Massachusetts.....	\$1,606,022.82	8,699,500.00
Rhode Island.....		1,800,000.00
Connecticut.....		7,000,000.00
Total.....	1,606,022.82	18,959,500.00

ROAD MILEAGE.

The total mileage in the New England States, as of January 1, 1915, was shown by the detailed investigations to be 86,718, excluding streets in cities. Of this total, 18,038.78 miles, or 20.8 per cent, were reported as surfaced. This surfaced mileage is less than the surfaced mileage reported for 1909, but the returns are much more accurate than it was possible to obtain in 1909, and the difference should not be considered to indicate any neglect of the roads in the New England States, but rather to show that road statistics are now reaching the bed rock of exact record as a development from the method of approximation upon which we have had to rely in the past. Furthermore, streets in incorporated cities have been excluded more rigidly in the 1914 investigation than in that of 1909, and a higher standard

was maintained in the 1914 classification of surfaced roads than in the 1909 classification. Table 4 shows total and surfaced mileage for 1914, and the percentage of mileage surfaced in 1914, and 1909, respectively.

TABLE 4.—*Road mileage.*

State.	Total road mileage at close of 1914.	Miles surfaced at close of 1914.	Percentagesurfaced.	
			1914	1909
Maine.....	23,537	2,762.36	11.74	10.10
New Hampshire.....	14,020	1,659.63	11.83	9.58
Vermont.....	14,249	1,442.03	10.12	18.40
Massachusetts.....	18,681	8,505.89	45.53	49.00
Rhode Island.....	2,170	693.42	31.95	49.14
Connecticut.....	14,061	2,975.45	21.16	21.09
Total and average.....	86,718	18,038.78	20.80	22.22

The relation of total mileage and surfaced mileage to area and rural population for the years 1914, 1909, and 1904 is presented in Table 5.

TABLE 5.—*Relation of total mileage and surfaced mileage to area and rural population,*

State.	Total mileage.						Surfaced mileage.					
	Per square mile of land area.			Per 1,000 rural population.			Per square mile of land area.			Per 1,000 rural population.		
	1914	1909	1904	1914	1909	1904	1914	1909	1904	1914	1909	1904
Maine.....	0.79	0.85	0.85	65.3	70.7	71.5	0.092	0.090	0.078	7.65	7.49	6.51
New Hampshire.....	1.55	1.67	1.67	79.9	86.2	81.5	.184	.160	.143	9.47	8.25	6.98
Vermont.....	1.56	1.58	1.59	76.2	77.0	71.0	.158	.291	.214	7.71	14.17	9.55
Massachusetts.....	2.32	2.15	2.13	77.5	71.6	71.7	1.058	1.053	.976	35.29	35.11	32.92
Rhode Island.....	2.03	1.99	2.21	120.8	118.1	112.9	.649	.977	.957	38.59	58.03	48.83
Connecticut.....	2.92	2.61	2.92	122.3	109.5	121.7	.617	.629	.490	25.89	26.39	20.39
Average.....	1.40	1.40	1.43	80.3	79.3	79.1	.291	.312	.271	16.44	17.63	14.97

TYPES OF SURFACED ROADS.

Of the 18,038.78 miles of surfaced roads in the New England States at the close of 1914, 10,896.08 miles, or 60.40 per cent, were gravel; 2,229.81 miles, or 12.36 per cent, macadam; 1,771.20 miles, or 9.83 per cent, bituminous macadam, including roads built by the mixing and penetration methods and surface treated; 1,113.43 miles, or 6.17 per cent, sand-clay; 41.80 miles, or 0.23 per cent, concrete; 1.38 miles, or 0.01 per cent, brick, and 1,985.08 miles, or 11 per cent, surfaced with other materials of which the classification was not given. The distribution of types of surfaced roads, as of January 1, 1915, is shown by States in Table 6.

TABLE 6.—*Types of surfaced roads.*

State.	Macadam.	Bituminous macadam.	Gravel.	Sand-clay.	Brick.	Concrete.	Miscellaneous.	Total.
	<i>Miles.</i>	<i>Miles.</i>	<i>Miles.</i>	<i>Miles.</i>	<i>Miles.</i>	<i>Miles.</i>	<i>Miles.</i>	<i>Miles.</i>
Maine.....	55.36	43.93	1,139.36	2.26	0.05	10.51	1,510.89	2,762.36
New Hampshire.....	61.87	154.26	1,013.70	270.90	.....	7.07	151.83	1,659.63
Vermont.....	1.94	.....	1,165.42	.....	.....	.....	1,274.67	1,442.03
Massachusetts.....	834.30	1,337.33	6,289.57	.....	.....	.....	44.69	8,505.89
Rhode Island.....	352.92	107.4	230.10	.....	.....	.....	3.00	693.42
Connecticut.....	923.42	128.28	1,057.93	840.27	1.33	24.22	.....	2,975.45
Total.....	2,229.81	1,771.20	10,896.08	1,113.43	1.38	41.80	1,985.08	18,038.78
Per cent of total surfaced.....	12.36	9.83	60.40	6.17	.01	.23	11.00	100.00

¹ Gravel telford.

The detailed tables, reference to which is made in the chapters devoted to the several States, will be found in the Appendix.

MAINE.

By LUCIUS D. BARROWS, *Collaborator.*

Maine has a land area of 29,895 square miles, a total road mileage of 23,536.91, and a population, according to the 1910 census, of 742,371. The State, therefore, has a population of 24.83 per square mile of area and 31.53 per mile of road, with 0.79 mile of road per square mile of area. Of the total population in 1910, 48.6 per cent, or 360,928, was rural, an average of 15.33 per mile of road.

The northeastern part of Maine, especially the eastern part of Aroostook County, is devoted almost entirely to farming. The western part of Aroostook County and the northern parts of Penobscot, Piscataquis, Somerset, Franklin, and Oxford Counties are largely wild lands. In these sections lumbering is the principal industry, and there are very few roads. A great many summer resorts are located along the Atlantic coast line from Kittery to Eastport, while many summer camps, sporting camps, and summer hotels are found along the rivers and on the inland lakes. Many people now come to Maine in the summer by automobile. This summer tourist travel and the great increase in the number of automobiles owned in the State, together with the need for good roads on the part of the farming districts, have given a great impetus to road building in Maine.

The State has many rivers and streams, and the construction and maintenance of bridges is no small problem. From an investigation made in 1907, it was learned that there are more than 6,800 bridges in the State. Many of the larger bridges have been constructed under special legislative appropriations.

State and State-aid highways and the maintenance of the same are under the direction of the State highway commission, consisting

of three members appointed by the governor with the advice and consent of the council. A chief engineer, who is required to be a civil engineer having experience in and knowledge of highway construction, is appointed by the commission with the approval of the governor and council. The chief engineer, under the direction and control of the commission, has general charge of all construction and maintenance work to which financial aid is extended by the State, and may, with the approval of the commission, employ necessary engineering and clerical assistance. State highways are constructed at the expense of the State from the proceeds of a bond issue of \$2,000,000, authorized by the legislature of 1913. State-aid highways are constructed at the joint expense of the State and town. The amount of State aid apportioned to each town depends on the amount raised by the town, and is also limited by the valuation of the town.

State and State-aid highways are maintained at the joint expense of the State and town. The amount appropriated depends on the mileage and a rate per mile for State and State-aid highways as determined by the State highway law. Up to 1913 there was no systematic method for maintaining State and State-aid highways. A department of maintenance was organized by the State highway commission in 1913, which now looks after the maintenance of these roads. An effort will be made to increase the scope of this department so as to include a part of the town roads under its supervision at the joint expense of the State and town.

Maine now appropriates \$300,000 annually for the construction of State-aid roads and \$50,000 for the administration of the office of the State highway commission. Any surplus from the latter amount may be used for maintenance. The revenue received from the licensing and registration of automobiles is used to take care of the bond issue of \$2,000,000, and any surplus not needed for this purpose may be used for maintenance.

In this State the town is the governmental unit in the local administration of road and bridge construction and maintenance. Appropriations for roads and bridges are made by vote of the people at each annual town meeting. These appropriations are expended under the general direction of a board of selectmen, consisting of three members, and under the immediate direction of a road commissioner appointed by the selectmen. The labor tax has been abolished.

REVENUES APPLIED TO ROADS AND BRIDGES.

The total revenue applied to roads and bridges in 1914 amounted to \$2,642,006.79. Of this amount \$978,786.57 was expended by the towns on town roads and bridges, and \$1,663,220.22 was expended by the State highway commission from State aid, automobile funds,

special appropriations, State highway loan funds, and local funds. The amounts expended under the direction of the State highway commission are shown in the report of the commission for the year 1914, as follows:

	State.	Local.
Joint fund for construction of State-aid roads.....	\$410,781.28	\$338,051.48
State highway construction from State highway loan fund.....	763,143.09	
State-aid maintenance.....	59,949.50	31,667.17
State maintenance.....	12,858.34	4,120.40
Total for construction and maintenance of State and State-aid roads...	1,246,732.21	373,839.05
Amount paid by the State.....		1,246,732.21
Amount paid by the towns.....		373,839.05
Administration of State highway department.....		42,648.96
Grand total expended under State highway department.....		1,663,220.22

The total revenue applied to roads and bridges in 1904 amounted to \$1,472,393.70, thus indicating an increase in the 10-year period of \$1,169,613.09, or 79.43 per cent. Information regarding rates of taxation and amounts obtained from town taxes for town roads and bridges during 1914 is shown in Table 7.

ROAD AND BRIDGE BONDS.

The towns of Maine have no road and bridge bonds outstanding. On September 1, 1913, the State issued \$300,000 of State highway bonds and on July 1, 1914, additional State highway bonds amounting to \$492,500 were issued, making a total of \$792,500. One bond of \$7,500 was paid on September 1, 1914, which left a total outstanding on January 1, 1915, of \$785,000. These bonds bear 4 per cent interest and are to be retired by the serial plan. The bonds issued September 1, 1913, are to be retired at the rate of \$7,500 annually between September 1, 1914, and September 1, 1953. The issue of July 1, 1914, falls due annually in equal amounts of \$11,500 between July 1, 1915, and July 1, 1954. The State law provides that the interest and the bonds are to be paid from automobile registration fees and that not more than \$500,000 may be issued in any one year, provided that the total amount outstanding never shall exceed \$2,000,000.

ROAD MILEAGE.

At the close of the year 1914, Maine had 23,536.91 miles of public road, of which 2,762.36 miles, or 11.74 per cent, were surfaced. Of the surfaced roads, 43.93 miles were bituminous macadam, 55.36 miles macadam, 1,139.36 miles gravel, and 1,523.71 miles of other materials, of which the classification was not given, except as follows: brick, 0.05 mile; concrete, 10.51 miles; sand-clay, 2.26 miles.

In 1909 Maine had 2,592.09 miles, or 10.1 per cent, of roads surfaced, thus indicating an increase in the five-year period, 1909-1914, of 170.27, miles, or 1.64 per cent.

The mileage figures for 1914 are presented by counties and towns in Table 16.

NEW HAMPSHIRE.

New Hampshire has a land area of 9,031 square miles, a total road mileage of 14,020.10, and a population, according to the 1910 census, of 430,572. The State, therefore, has a population of 47.67 per square mile of area and 30.71 per mile of road, with 1.55 miles of road per square mile of area. Of the population in 1910, 40.8 per cent, or 175,473, was rural, an average of 12.51 per mile of road.

In 1905 the governor and council were authorized by law to appoint a State engineer and such other engineers as might be deemed necessary for the purpose of carrying on road work undertaken by the State. In 1915 a new act was passed empowering the governor and council to appoint a highway commissioner skilled in the construction and maintenance of highways. The highway commissioner exercises general supervision, control, and direction, on behalf of the State, over all matters pertaining to the location, construction, and maintenance of highways now or hereafter built or maintained, either in whole or in part, with money appropriated from the State treasury. He is vested with power to fix or decide all matters pertaining to the location and route of any such highways, methods of construction, materials, manner in which such highways shall be maintained, and all other matters pertaining thereto, including award of contracts. Appeals may be taken from his decision to the governor and council. The highway commissioner was authorized to designate a system of cross-State highways for improvement, the cost to be borne one-half by the State and one-half by the town, city, or place within which such road is located, provided that where the town is financially unable to pay one-half of such cost, the State may pay such further sums in addition to its one-half as the State highway commissioner may deem equitable. Any cross-State highway may be improved by the city, town, or place within which it is located at the expense of the city, town, or place, and to the satisfaction of the State highway commissioner. In which event the State shall reimburse such city, town, or place.

Under an act passed in 1913, a system of trunk-line highways was designated for improvement by the governor and council and an issue of State bonds was authorized to meet the cost, but cities and towns through which such highways passed were to pay one-half the cost, less such portion thereof as the governor and council might deem equitable in towns unable to pay their share. By an act of 1903 a system of State highways was outlined for improvement and

maintenance at the sole expense of the State, and appropriations were made therefor.

Each town is required to set apart for the permanent improvement of its main highways, to be done under the advice of the State highway commissioner, and to which the State is to contribute aid, an amount varying from \$1 on each \$1,000 of assessed valuation where the valuation is less than \$2,000,000, to 25 cents on each \$1,000 of assessed valuation where the valuation is \$15,000,000 and upward. The amount appropriated by the State for State aid is required to be apportioned by the governor and council to each city, town, and unincorporated town or place which has applied for State aid in proportion to the amount locally set aside in accordance with the above provisions. The apportionment varies according to assessed valuation from \$3 for each \$1 so set apart, where the valuation is less than \$100,000, to 20 cents for each \$1 so set apart, where the assessed valuation is \$3,000,000 and upward. Applications for State aid each year are required to be made on or before May 1. Money locally so raised, together with the amount apportioned by the governor and council, constitutes a joint fund for the permanent improvement of such main highway in accordance with plans and specifications prepared by the highway commissioner. Where the joint fund exceeds \$1,000, the work shall be done by contract.

The boards of selectmen of the several towns have general charge and supervision of all matters pertaining to roads and bridges in their respective towns. Under certain conditions, a petition for laying out or altering a road may be filed in the office of the clerk of the supreme court and the court may refer such petitions to the county board of commissioners for investigation and report. The county board of commissioners has jurisdiction over roads and bridges in unincorporated towns and places. At the annual election each town shall elect one or more, not exceeding three, highway agents, or may instruct its selectmen to appoint a highway agent, who, under the direction of the selectmen, shall have charge of the construction and repair of all highways and bridges within the town.

Towns may authorize the selectmen to contract for keeping their highways and bridges, or any part thereof, in repair for a term of not exceeding five years. Each town is made to constitute a highway district, but may be divided into smaller districts in charge of a surveyor of highways.

Each town shall, at its annual meeting, raise and appropriate for the repair of highways and bridges a sum not less than one-fourth of 1 per cent of the valuation of the polls and ratable estate on which other taxes are assessed by the towns and as much more as the town may deem necessary, but no town shall be required to raise more than \$50 per mile for the repair of roads and bridges. The supreme court,

on petition and notice to the county commissioners, may order any part of the expense of repairing a highway paid by the county when the whole would be burdensome to the town or when the county convention has recommended such order. When the expense of rebuilding or repairing a highway is excessively burdensome to the town in which it is situated, the supreme court, upon petition and proceedings thereon, as in the case of laying out a highway, may order a portion of such expense paid by the other towns that will be benefited thereby.

All the moneys obtained from automobile licenses are awarded by the highway commissioner to the respective towns for the purpose of maintaining the roads previously built under the State-aid law, or built under trunk-line appropriations. This money is divided 65 per cent to trunk lines and 35 per cent to State aid. The highway commissioner notifies each town of the amount estimated as necessary to maintain its State-aid and trunk-line roads for the coming season, and adds to this apportionment certain sums, provided the town raise a fixed sum. This fund is expended under the direction of the State highway commissioner.

REVENUES APPLIED TO ROADS AND BRIDGES, 1914.

The total revenues applied to roads and bridges in 1914 amounted to \$1,590,464.11, comprising the following items: Town appropriations for town roads, \$788,291.11; contributions by towns to State-aid roads, \$301,288; State contributions to State-aid roads, \$491,520; and expenditures by State for work done solely at State expense, \$9,365. Of the \$491,520 contributed by the State for State-aid work, \$271,767 was for construction, \$157,155 was for maintenance, \$11,995 for administration, and \$50,603 for miscellaneous equipment. Of the \$301,288 contributed by the towns, \$225,000 was for construction and \$76,288 was for maintenance.

The total revenues applied to roads and bridges in 1904 amounted to \$872,606.35, of which the State contributions were \$44,000. It thus appears that the revenues applied to this purpose increased in 1914 over 1904 \$717,857.76, or 82.2 per cent.

The amounts appropriated by towns for town roads are shown by counties and towns in Table 8.

ROAD AND BRIDGE BONDS.

According to the report of the State auditor, there was outstanding, September 1, 1914, a total of \$675,000 of State highway bonds. These bonds are deferred serial in character, payable between 1915 and 1924, and bear 3 to $3\frac{1}{2}$ per cent interest.

ROAD MILEAGE, 1914.

According to the reports from the towns, New Hampshire had, at the close of the year 1914, a total of 14,020.10 miles of public road, of which 1,659.63, or 11.83 per cent, were surfaced. Of the surfaced roads 1,013.7 miles were gravel, 270.9 miles sand-clay, 154.26 miles bituminous macadam, 61.87 miles macadam, 7.07 miles concrete, and 151.83 miles of materials not classified as to type.

In 1909, New Hampshire reported a total of 1,448.48 miles, or 9.58 per cent, of surfaced roads, thus indicating an increase in the 5-year period of 211.15 miles.

The mileage figures for the year 1914 are presented by counties and towns in Table 17

VERMONT.

Vermont has a land area of 9,124 square miles, a total road mileage of 14,248.66, and a population, according to the 1910 census, of 355,956. The State, therefore, has a population of 39.01 per square mile of area and 24.98 per mile of road, with 1.55 miles of road per square mile of area. Of the population in 1910, 52.5 per cent, or 187,013, was rural, an average of 13.12 per mile of road.

A State highway commissioner is appointed biennially by the governor, with the advice and consent of the senate. He controls and directs the expenditure of all moneys appropriated by the State or apportioned to towns or incorporated villages for highway improvement. He appoints annually, with the advice and consent of the governor, a supervisor for each county, who, under his direction and control, assists in supervising the expenditure of State road funds and in the construction and inspection of roads that have been or may be built with State money.

All money appropriated by the State is required to be expended for improving permanently that main thoroughfare in each town selected by the selectmen and town road commissioners, subject to the approval of the State highway commissioner. Such roads are known as State roads and are required to be selected with a view to securing trunk lines of improved highways. The location of each year's work, plans and specifications therefor, and the appointment of foremen to have charge of the work, are determined by the State highway commissioner after consulting selectmen and road commissioners. The State highway commissioner has the same powers in all matters pertaining to highways and bridges in unorganized towns and gores as have selectmen and road commissioners in organized towns.

Appropriations are made by the legislature for apportionment by the State highway commissioner to cities and towns, excluding incorporated villages, the basis of apportionment being that the State shall

duplicate such amount as may be voted by the town in excess of the amount otherwise required by law to be raised, provided the town so raises not less than \$100 nor more than \$1,000. An appropriation is made annually as a "bridge fund" to enable the State highway commissioner to furnish engineering assistance to the town selectmen in building, rebuilding, or repairing bridges on selected or State roads. A State highway tax of 5 cents on the dollar is assessed annually upon the "grand list," which is arrived at by taking 1 per cent of the assessed valuation. The revenues derived therefrom are apportioned to the towns and incorporated villages by the State treasurer in the ratio of the highway mileage of such town or incorporated village to the total road mileage of the State.

The net revenues from automobile registrations and licenses are set apart as a maintenance fund to be expended only for repair and maintenance of main thoroughfares and State roads. Towns are required to appropriate annually a sum not less than one-fifth of their grand lists to keep highways in repair. No part of the funds raised from town or State highway taxes or appropriated by the State for highway improvements shall be used in repairing, building, or rebuilding bridges or culverts, or the approaches thereto, which exceed 4 feet span. These shall be under the exclusive control of the selectmen, who shall repair and rebuild them when necessary with funds to be raised in the general town tax.

Selectmen have jurisdiction over the laying out, alteration, discontinuance, and working of roads and bridges in their respective towns. A town road commissioner is elected by the town for the purpose of superintending the expenditure of the highway tax and having charge of keeping in repair the highways of the town. A town may elect two road commissioners, in which event the selectmen shall divide the town into two highway districts, one in charge of each commissioner. The county court in each county appoints annually three county road commissioners. If a highway or bridge be out of repair or unsafe, any three citizens or taxpayers of a town may give notice thereof to a selectman, and if the necessary repairs are not then made, complaint may be filed with one of the county road commissioners, who may order the necessary repairs made at the expense of a town within a specified time if the selectmen, after notice, neglect to do so.

If a town in which the tax for town purposes, except for schools, together with the money expended on its highways in the preceding 5 years, has averaged at least \$1.50 on the dollar of its grand list, believes it is excessively burdened by being required to build, rebuild, or repair a highway or bridge wholly in such town, and other town or towns would be especially benefited by the use of such highway, the town so burdened may petition the county court for commissioners

to hold hearings, and, if justified, assess not exceeding one-half of the cost to the State and the balance to the petitioning town. The commissioners shall report their findings to the county court and the court shall render judgment thereon.

The working of county prisoners on the public highways is authorized by law.

REVENUES APPLIED TO ROADS AND BRIDGES.

All funds applied to roads and bridges in 1914 amounted to \$1,023,941.01, of which the towns raised \$617,327.79 and the State contributed from appropriations and automobile revenues a total of \$406,613.22.

Of the amount raised by the towns, \$388,542.63 was for construction and maintenance of town roads, \$16,346.42 for resurfacing of town roads, \$96,754.36 was raised under the 5 per cent State road tax, and \$115,684.38 was contributed by the towns for State-aid roads. These items do not include expenditures for the construction and maintenance of culverts and bridges over 4-foot span, or for snow removal, or for winter roads. Appropriations for these purposes are made from town funds, and no records of the amounts expended are available.

The amounts contributed by the State are for the fiscal year ended June 30, 1914, and are shown in the State auditor's report for 1914, as follows:

Salary and expenses of State highway commissioner.....	\$7, 153. 59
Salary and expenses of county supervisors.....	19, 347. 60
State aid to towns.....	10, 000. 00
Permanent highway work (appropriation).....	272, 847. 04
Automobile maintenance fund (paid to towns).....	70, 852. 12
State funds expended on bridge work.....	5, 360. 87
Elimination of grade crossings (State's share).....	21, 052. 00
Total.....	406, 613. 22

The total revenue applied to roads in 1904 amounted to \$567,397.33, of which the towns raised \$440,016.12 and the State appropriated \$127,381.21. Thus revenues for roads and bridges increased \$456,543.68, or 80.4 per cent. No bonds were reported as issued or outstanding.

Information regarding receipts from town taxes for town and State-aid roads is presented in Table 9.

ROAD MILEAGE.

According to reports collected from the towns by the collaborator, Vermont had at the close of 1914, 14,248.66 miles of public road, of which 1,442.03 miles, or 10.12 per cent, were surfaced. Of the surfaced roads 1,165.42 miles were gravel, 274.67 miles gravel-telford, and 1.94 miles of macadam. According to the 1909 report, Vermont

had 14,406 miles of public road, of which 2,650.63 miles, or 18.40 per cent, were reported as surfaced, thus indicating a loss in surfaced mileage for the 5-year period of 1,208.6 miles. The 1914 information was obtained from town officials by the collaborator, and it is believed that it is much more reliable than the figures furnished for 1909, and the difference should therefore not be attributed to any failure on the part of the State or the towns to give adequate attention to the roads. No reports were obtained as to the mileage of graded and drained roads.

Information showing the total mileage and the mileage surfaced for each town in the State is presented in Table 18.

MASSACHUSETTS.

Massachusetts has a land area of 8,039 square miles and a population, according to the 1910 census of 3,366,416. The total mileage of roads outside of cities in 1914 was reported as 18,681.40. The State has a population of 418.8 per square mile of area and 180.2 per mile of road, with 2.32 miles of road per square mile of area. Of the population in 1910, only 7.2 per cent, or 241,049, was rural, thus indicating a rural population of 12.90 per mile of road. There are 36 cities, 14 counties, and 317 towns in the State, the towns being political subdivisions of the counties.

HIGHWAY LAWS.

There is practically no unincorporated land in Massachusetts. Many of the towns were organized before the State and the representatives of the towns met and adopted a form of constitution. There were no cities until 1820, when a constitutional amendment was passed authorizing the legislature to give a city charter to towns of more than 12,000 inhabitants.

All of the highways within the limits of a city or town were originally under the jurisdiction of the city or town, and had to be built and maintained by them.

In general, the highways in Massachusetts are divided into three classes, as follows: State highways, county highways, and city or town ways. The county, city, or town ways are cared for by the municipal authorities, viz, superintendents of streets, road commissioners, and highway surveyors. The provisions in cities vary, the jurisdiction being sometimes placed in boards of commissioners and sometimes in boards of aldermen. The appropriations for either improvements or repairs are made by the city government or at a town meeting.

County commissioners, upon proper petition and after due hearing, have authority to lay out new ways or to widen and improve existing ways and order specific repairs, or may make such repairs themselves

and determine what part of the cost thereof shall be paid by the city or town benefited. The county assesses a tax on the municipalities, and this tax, as well as the State tax, is collected by the towns and cities in connection with the municipal tax.

Cities and towns acting through their proper authorities also have authority to lay out and construct new ways and to widen and improve existing ways, and naturally can direct their improvement and appropriate money therefor.

HIGHWAY COMMISSION.

The Massachusetts highway commission was established in 1893. It consists of three members appointed by the governor with the advice and consent of the council, to serve for a term of three years, one term expiring each year. Its duties in relation to highways are twofold; first the collection and collation of statistics as to road materials, etc., the making of maps, designation of highways, and the giving of advice on road matters to the various authorities throughout the Commonwealth who have charge of road building or road maintenance; and, second, the laying out and construction of State highways and the improvement of certain town roads.

STATE HIGHWAYS.

Since 1894 appropriations have been made by the legislature for the construction of what are known as State highways. The total length of State highways at the end of 1914 amounted to 1,039.07 miles. The money is raised by a bond issue, usually authorized in 5-year periods. The highway commission may lay out as a State highway a new or existing way in any city or town upon petition of the city government, board of selectmen, or the county commissioners. When so laid out it is maintained by the commission and the commission has entire jurisdiction over it, even to the extent of determining the location of water and gas mains, poles, and other structures. A road becomes a State highway when copies of the petition, layout plan, and adjudication are filed in the offices of the clerk of the county commissioners and the clerk of the city or town.

When a State highway is laid out and constructed by the commission, the county in which it is located repays to the Commonwealth, within 6 years, 25 per cent of the cost of construction, and the towns and cities repay to the Commonwealth from \$50 to \$500 a mile a year on account of maintenance, according to valuation, provided twice as much is spent.

SMALL-TOWN ROADS.

The commission may spend 15 per cent of the amount appropriated for State highway construction under the so-called small-town act as follows: Five per cent in towns of less than \$1,000,000 valuation upon

petition, the towns making no contribution; 5 per cent in towns of less than \$1,000,000 valuation upon petition, the town contributing an equal amount; and 5 per cent in towns of more than \$1,000,000 valuation upon petition, the town contributing an equal amount. These roads remain town ways, and the towns are responsible for their maintenance and for any accident which may happen thereon. The commission has authority, however, to repair such roads and to charge back to the towns in which they are located the cost of the repairs, not to exceed \$50 a mile a year.

EXPENDITURES FOR STATE HIGHWAYS AND SMALL TOWN ROADS.

From the time improvement of highways was started under the highway commission up to November 30, 1915, the Commonwealth has expended \$12,167,800 in the construction of State highways and work under the small-town act, including the planting of trees. There were 1,039 miles of State highway November 30, 1914, and 1,101 miles April, 1916, located in 329 cities and towns. About 482 miles of road have been improved under the small-town act, and 265 miles under the motor-vehicle fees fund act.

REVENUES APPLIED TO ROADS.

In 1914 the towns expended \$3,839,094.23 for highway construction and maintenance. The State highway commission expended for repair, maintenance, and construction of highways in towns, exclusive of the cost of administration of the State automobile department, \$2,252,781.07, making a total of \$6,091,875.30. The appropriations by towns comprised the following items: for highway construction, \$1,295,198.40; highway repairs, \$2,182,104.25; for bridge construction, \$135,983.05; bridge repairs, \$61,182.77; amount paid State for State highways covering towns' share of cost, \$126,759.43; amount paid by towns to counties for county highways, \$37,866.33. The expenditures by the State highway commission for State highways in towns and exclusive of cities comprised the following items: for construction, \$878,235.16; for construction under small-town act, \$114,689.61; for road repair and maintenance, \$314,489.41; for repair and maintenance of town and county ways under motor-vehicle fees fund, \$167,614.74; repair and maintenance of State highways under motor-vehicle fees fund, \$426,299.30; for general expenses of the highway commission, \$71,322.37; expenditures under special acts, \$280,130.48.

The State highway commission also spent in 1914, for construction, repair, and maintenance in cities, \$212,837.76, and the cities themselves spent a total of \$6,693,206.83, making a grand total for highways and city streets of \$12,997,919.89.

In 1904 the total revenues applied to roads outside of cities amounted to \$2,871,222.47, of which \$2,295,616.48 was spent by the towns and \$575,605.99 by the State, thus showing an increase in this 10-year period of \$3,220,652.83, or 112.2 per cent. The town revenues applied to roads and bridges, outside of cities, in 1914, are shown by counties and towns in Table 10. City revenues applied to city streets, in 1914, are shown in Table 11.

ROAD AND BRIDGE BONDS.

The total road and bridge bonds and notes outstanding on January 1, 1915, amounted to \$10,305,522.82, of which \$8,699,500 were issued by the State and \$1,606,022.82 by the towns. State bonds issued between 1894 and 1904 were sinking-fund bonds maturing 26 to 30 years from date of issue. All State bonds issued since 1904 are deferred serial, with the first payment falling due from 3 to 11 years from date of issue, and the last payment from 9 to 30 years from date of issue. All State bonds bear from 3 to $3\frac{1}{2}$ per cent interest.

Of the money derived from town bonds and notes, there was expended in 1914 a total of \$440,639.50, and notes amounting to \$328,999.33 were retired by the towns in the same year. New notes were issued by the towns to the amount of \$511,437.25. Most of these are serial in character and are paid off in equal annual amounts between the first and fifth years from date of issue, although some are to be paid in less than a year, while the last payment on others extends to the twentieth and thirtieth years. Town bonds issued in 1914 bear from 3 to 6 per cent interest, depending upon date of maturity.

Information in regard to State highway bonds is presented in Table 14. Town road and bridge bond information is contained in Table 15.

ROAD MILEAGE.

Information furnished by the Massachusetts highway commission indicates that at the close of the year 1914 Massachusetts had, outside of incorporated cities, 18,681.4 miles of public road, of which 8,505.89 miles, or 45.53 per cent, were surfaced. Of the surfaced roads, 834.30 miles were macadam, 1,337.33 bituminous macadam, 6,289.57 gravel, and 44.69 of various types. The cities had 4,349.44 miles of streets, of which 3,812.26 miles, or 86.76 per cent, were surfaced as follows: 1,464.61 miles gravel, 1,183.85 plain macadam, 430.06 bituminous macadam, and 404.25 of various classes.

According to the information furnished for 1909, Massachusetts had 17,272 miles of public roads outside of cities, of which 8,463.18 miles, or 49 per cent, were surfaced, thus indicating a gain in the 5-year period of only 45.53 miles in surfaced road. This small gain probably is due to the fact that in some cases improved or

surfaced city streets may have been included as county roads in 1909 and that city streets were, in some cases, excluded from the total mileage.

Information showing the total mileage and the mileage of surfaced roads outside of cities at the close of 1914 is shown by counties and towns in Table 19.

RHODE ISLAND.

By PETER J. LANNON, *Collaborator*.

Rhode Island is the smallest and one of the most densely populated States in the Union. It has a land area of 1,067 square miles, a total road mileage of 2,169.70, and a population, according to the 1910 census, of 542,610. The State, therefore, has a population of 508.5 per square mile of area and 250 per mile of road, with 2.03 miles of road per square mile of area. Of the 1910 population, 3.3 per cent or 17,956 was rural, thus indicating a rural population of 8.28 per mile of road. The State is not well provided with good road materials. A magnetic iron ore ranks as the best and granitic rock and trap are next in value. Puddingstone and conglomerate and gravel form a fair material for road use.

THE STATE ROAD SYSTEM.

The present board of public roads created in 1902 was the outgrowth of the joint committee appointed in 1892 and the highway commissioner appointed in 1896 and abolished in 1902. The board consists of 5 members appointed by the governor and serving 5 years each. They have charge of the construction and maintenance of all State roads and of the bridges on these roads. Seven hundred miles have been selected as the State roads, but only 325 miles are legally under State control. The roads become State roads only when they have been improved or reconstructed by the State board. The State bridges are repaired and reconstructed by the board and the cost paid by them in the first place and then a proportion of the cost charged against the cities or towns in which the bridge lies, but the State is obliged to pay 50 per cent of this cost. Public utility companies using the bridges also are assessed for a portion of the cost.

In addition to the 325 miles of State road there are 1,844 miles of local roads. Of the State roads, 89 miles are bituminous macadam and the rest surface-treated waterbound macadam.

All construction is done by contract and the State maintains waterbound macadam by the patrol system and a yearly oiling. Bituminous macadam is maintained by section gangs. Convicts are not used.

The State board derives its revenue from appropriations, bond issues, and the automobile fines and fees. From 1903 to 1914 there

was expended under the State board of public roads a total of \$3,641,032.83 for construction, repair, and maintenance of State and State-aid roads. There is no direct tax for State roads.

STATE AID.

Whenever a town makes an appropriation equal to or more than 20 cents on the \$100 valuation and directs that the money shall be spent under the direction of the State board, it shall be entitled, according to the law of 1910, to State money aid equal to one-fifth of the money appropriated by the town.

THE LOCAL ADMINISTRATION.

The administration of local roads, other than State roads, is vested in the towns or cities themselves. There is no county administration. There is no direct tax. The money for roads and bridges is spent from the general fund. The taxpayers make an appropriation for roads and bridges and this is spent by the road commissioner or highway committees, either elected by the people or appointed by the town council, or the towns are divided into road districts and a commissioner is appointed for each district by the town council. In some towns the members of the town council are the highway commissioners and take care of their own districts.

REVENUES APPLIED TO ROADS AND BRIDGES, 1914.

In 1914 the total revenues applied to roads and bridges amounted to \$446,496.05, of which the State funds amounted to \$202,496.05, and the town funds \$244,000. Of the State funds, \$5,000 was for office and traveling expenses of the State board of public roads, \$168,981.56 derived from automobile registrations and other sources was for the maintenance and repair of State roads, \$4,920.71, balance on hand, expended for construction of State highways, and \$23,593.79 for bridge construction and repair.

The total revenues applied to roads in 1904 amounted to \$405,010.85, thus showing an increase for the 10-year period of \$41,485.20, or 10.2 per cent. Of the total revenues applied to roads in 1904 the town revenues amounted to \$297,414.71 and the State revenues to \$107,596.14.

Information in regard to town revenues devoted to roads and bridges in 1914 is shown in Table 12.

ROAD AND BRIDGE BONDS.

No bonds have been issued by counties or towns, but the State has issued \$1,800,000 of bonds for the purpose of building State roads, \$600,000 having been authorized in each of the years 1906, 1909, and 1912. These are sinking-fund bonds issued for 30 years and bear interest at the rate of 3, 3½, and 4 per cent, respectively.

ROAD MILEAGE, 1914.

According to reports received from the towns, Rhode Island, at the close of 1914, had 2,169.70 miles of public road, of which 693.42 miles, or 31.95 per cent, were surfaced. Of the surfaced roads 352.92 miles were macadam, 107.40 bituminous macadam, 230.10 gravel, and 3 miles granite block. According to the 1909 report, the State had 2,120.75 miles of public roads, of which 1,042.07 miles, or 49.14 per cent were surfaced, a decrease in surfaced mileage for the 5-year period of 348.65 miles. This apparent decrease probably is due to overestimates in 1909.

Information in regard to road mileage for each town in the State is shown in Table 20.

CONNECTICUT.

By C. G. NICHOLS, *Collaborator and Chief Clerk, Connecticut Highway Department.*

Connecticut has a land area of 4,820 square miles, a total road mileage of 14,060.82, and a population, according to the 1910 census, of 1,114,756. There is a population of 231.3 per square mile of area, and 79.28 per mile of road, with 2.92 miles of road per square mile of area. Of the population in 1910, 10.3 per cent, or 114,917, was rural, or 8.17 per mile of road.

The State has 8 counties, 157 towns (or townships), 10 cities, and 1 borough. Within the boundaries of 33 of the towns there are 9 additional cities and 24 boroughs. In these latter cases, however, the city or borough and the town lines are not coincident, but are really incorporated communities separate and distinct from the town government. From this system of creating such communities within towns comes the expression "New England's borough system," which affords certain complications in the apportioning of money for road and bridge purposes. The plan adopted generally in these cases is for the town, through its proper officials, to apportion to the city or borough a certain sum for construction and maintenance of roads within the borough limits.

ROAD ADMINISTRATION.

There are three county commissioners in each county. If any town neglects or refuses to maintain roads properly, petition may be filed with the county commissioners, who, after a hearing, may order the town to make necessary repairs. The town failing, the commissioners may have the work done and charge the expense to the town. All road matters in towns are under the jurisdiction of the board of selectmen, usually three in number, unless the town has placed the control of highways in the hands of a superintendent of streets, a highway commissioner, or similar official. The larger towns are gradually adopting the "centralized authority" feature of road

work, with the result that in several instances road matters have been removed from the hands of the selectmen.

Generally the towns do not levy a special road tax. At the town meeting, in most cases held the first Monday in October each year, a budget tax for all town purposes is levied. Part of the income from this tax is applied to roads. In a few of the larger towns there are boards of finance, the members of which attend to all matters of taxation, the apportioning of money, etc.

Until 1895 the State made no definite effort to control or assist in the work of road construction or maintenance. The General Assembly of 1895 created a highway commission of three members, and enacted the first State-aid law. The first appropriation by the State was \$75,000. This law provided that the cost of improvement of roads should be on the basis of one-third each by State, county, and town. The legislature of 1897 abolished the triple-headed commission and created the office of State highway commissioner. The counties were removed as a contributing factor, and the cost of improvements was to be paid one-half each by town and State. From year to year changes were made in the law and at present the basis of payment is as follows: In towns having a grand list of \$1,250,000 or more the State contributes three-fourths of the cost; in towns having a grand list of less than \$1,250,000, the State's pro rata is seven-eighths. The maximum amount allotted to any town in any one year, under the law has been \$15,000. The grand list is the total assessed valuation as fixed by the State board of equalization.

The first appropriation for the improvement of trunk-line highways was made in 1905. The trunk-line highways always have been built and maintained exclusively by State funds. To assist the highway department in this work, all money received from the registration of motor vehicles, fines, etc., is placed to the credit of the department; and, in addition, a specific appropriation for this purpose has been made by each legislature.

Prior to 1907, the State had no jurisdiction over the maintenance or repair of roads constructed under State aid. That year, however, full jurisdiction was given to the State highway department. The law provided that, irrespective of the amount of grand list, all towns should pay one-fourth of the cost of maintenance of State-aid roads within their limits.

The practice of "working out taxes" is virtually obsolete. In some of the very small towns the system is followed, but the aggregate amount of this item is so small as to be practically negligible. Poll taxes, now known in this State as the personal tax, are payable in cash.

The maintenance of all roads constructed by the State, both on trunk-line and State-aid highways, is in direct charge of the State highway commission. The actual work is looked after by a superintendent of repairs. The State is divided into nine districts for the purpose of maintenance, each of which is in charge of a supervisor of repairs. All of the State roads are under the "patrol system," the various workmen being under foremen, who report directly to the supervisors. The supervisors, the foremen, and a sufficient number of workmen to maintain the roads properly are employed during the entire year, constant attention being given to the roads at all seasons.

The State highway department purchases its own equipment, and during the past year has installed an automobile brigade. This has been a direct advantage both in cost of maintenance of roads and ability to cover a much larger area, as compared with horse-drawn vehicles. In the maintenance of their own roads, the selectmen of towns purchase their own equipment without reference to the State highway department.

By an act of the legislature in 1915, all bridges having a span of 25 feet or greater, on the trunk-line highways (with the exception hereinafter noted), were placed under the jurisdiction of the State highway department. Bridges over railroad or street-railway lines and bridges in towns having a population of 10,000 or more are not included; nor are bridges built or maintained under a special act of the legislature. Where any such bridge lies in a town, the cost is borne half each by the State and such town; where the bridge is between two towns or counties, the State pays one-half and the towns or counties one-fourth each. If there is a street railway line across such bridge, the town, towns, or counties pay one-third, the State one-third, and the street-railway company one-third. Much work already has been done under this law.

While the legislature from year to year has authorized bond issues, and these bonds have been sold, the revenue therefrom has been placed in the general account and has not been set apart distinctively as road-improvement funds. These bonds, therefore, can not be denominated road bonds. Money authorized for road construction and maintenance is placed to the credit of the State highway department from money not otherwise appropriated.

REVENUES APPLIED TO ROADS, FISCAL YEAR 1914-15.

The total revenues applied to roads in the fiscal year ended September 30, 1915, amounted to \$3,640,962.75, and comprised the following items: for construction of 84.91 miles of trunk-line roads, paid entirely by the State, \$869,627.40; for 78.16 miles of State-aid road, for which the State paid three-fourths to seven-eighths of the

cost, \$635,384.57; for maintenance of 895.7 miles of trunk-line roads, \$584,762.73; for maintenance of 490.37 miles of State-aid roads, \$166,150.67; for engineering and inspection on trunk-line and State-aid roads, \$94,065.93; overhead expenses for maintenance, \$78,190.87; for construction and maintenance of town roads, \$1,059,511.05; for construction and maintenance of town bridges, \$153,269.53. The last two items were for the calendar year 1914.

In 1904 there was expended for roads and bridges \$1,195,125, of which \$975,960 was expended by the towns on town roads and \$219,165 by the State on State-aid roads. It thus appears that from 1905 to 1914, the revenues applied to roads increased \$2,445,837.75, or 204.6 per cent. The revenues applied to town roads and bridges in the fiscal year 1914-15 are shown in Table 13.

ROAD AND BRIDGE BONDS.

No town bonds have been issued for road purposes, but the State issued, between 1907 and 1913, inclusive, \$7,000,000 of State bonds, a large portion of which were used for paying the State's share of the cost of constructing State highways. These bonds bear $3\frac{1}{2}$ to 4 per cent interest and are retired by appropriation from the general State funds under the deferred serial plan, at the rate of from \$120,000 to \$205,000 annually. The last payment must be made by 1925, but the State treasurer is authorized to redeem them whenever and in such a manner as he deems to be for the best interest of the State.

ROAD MILEAGE OUTSIDE OF CITIES, 1914.

At the close of 1914 Connecticut had, according to reports received from the towns, 14,060.82 miles of public roads, of which 2,975.45 miles, or 21.16 per cent, were surfaced. Of the surfaced roads, 923.42 miles were macadam, 128.28 miles bituminous macadam, 1,057.93 miles gravel, 840.27 miles sand-clay, 1.33 miles brick, and 24.22 miles concrete. There were also 2,219.23 miles of earth roads reported as graded and drained.

The reports for 1909 indicate that there were 12,583 miles of public road, of which 2,654.27 miles, or 21.09 per cent, were surfaced, a gain for the 5-year period of 321.18 miles. The small increase in percentage of surfaced roads is due to the fact that the total mileage reported for 1914 exceeds the total reported for 1909 by 1,477.82 miles.

Information regarding road mileage is presented by counties and towns in Table 21.

APPENDIX A.

TABLES SHOWING ROAD AND BRIDGE REVENUES.

Following are the tables showing the local road revenues expended in the respective States comprising the New England group, referred to in the foregoing text:

MAINE.

TABLE 7.—*Town revenues applied to town roads and bridges, 1914.*

County and town.	Tax rate per \$1.	Amounts obtained.	County and town.	Tax rate per \$1.	Amounts obtained.
Androscoggin:			Aroostook—Continued.		
Durham.....	\$0.0057	\$2,250.00	Merrill Place.....	\$0.0069	\$1,000.00
East Livermore.....	.0022	4,000.00	Molunkus.....	.0048	565.92
Greene.....	.0078	3,050.00	Monticello.....	.0057	2,700.00
Leeds.....	.0044	1,500.00	Moro.....	.0149	1,100.00
Lisbon.....	.0015	4,000.00	Nashville Place.....	.006	598.49
Livermore.....	.0055	2,500.00	New Canada Place.....	.014	1,030.00
Mechanic Falls.....	.0018	1,500.00	New Limerick.....	.0048	800.00
Minot.....	.0047	1,800.00	New Sweden.....	.0049	2,000.00
Poland.....	.0033	3,400.00	Oakfield.....	.0093	1,500.00
Turner.....	.0052	5,000.00	Orient.....	.0111	1,000.00
Wales.....	.0045	1,150.00	Oxbow Place.....	.0052	521.43
Webster.....	.0045	2,700.00	Perham.....	.0057	1,600.00
Total.....		32,850.00	Portage Lake Place.....	.00226	400.00
Aroostook:			Presque Isle.....	.0049	13,500.00
Allagash.....	.0046	1,225.00	Reed Place.....	.00453	618.70
Amity.....	.0102	1,000.00	St. Agatha.....	.0124	2,030.00
Ashland.....	.0049	3,300.00	St. Francis Place.....	.00405	1,090.00
Bancroft.....	.0075	500.00	St. John Place.....	.03257	200.00
Benedicta.....	.0069	703.00	Sherman.....	.0078	3,500.00
Blaine.....	.0056	2,040.00	Silver Ridge Place.....	.00726	300.00
Bridgewater.....	.00507	2,500.00	Smyrna.....	.007	1,000.00
Caribou.....	.0034	10,000.00	Stockholm Place.....	.00217	1,075.00
Cary Plantation.....	.019	800.00	Van Buren.....	.00357	3,500.00
Castle Hill.....	.0095	1,500.00	Wade Place.....	.00524	900.00
Caswell Place.....	.0075	500.00	Wallagrass Place.....	.0139	1,500.00
Chapman.....	.009	1,150.00	Washburn.....	.0063	3,000.00
Connor Place.....	.0135	1,150.00	Westfield.....	.00758	2,650.00
Crystal.....	.0044	800.00	Westmanland Place.....	.0037	452.80
Cyr Place.....	.011	900.00	Weston.....	.0233	2,000.00
Dyer Brook.....	.0067	1,000.00	Winterville Place.....	.0056	433.62
E Place.....	.00479	365.81	Woodland.....	.0056	2,000.00
Eagle Lake Place.....	.0044	1,200.00	Letter A.....	.0047	274.50
Easton.....	.0029	1,808.00	No. 1—R. 4.....	.0051	400.00
Forkstown.....	.0026	302.36	No. 1—R. 5.....	.0052	677.40
Fort Fairfield.....	.0032	10,000.00	No. 7—R. 5.....	.0037	457.46
Fort Kent.....	.0064	4,000.00	No. 8—R. 5.....	.0041	576.92
Frenchville.....	.0078	1,500.00	No. 9—R. 5.....	.0111	1,160.51
Garfield Place.....	.0027	325.88	No. 11—R. 4.....	.0038	405.73
Glenwood Place.....	.0045	400.00	No. 17—R. 5.....	.0063	435.26
Grand Isle.....	.007	1,300.00	No. 14—R. 6.....	.0044	440.80
Hamlin Place.....	.00504	500.00	No. 15—R. 6.....	.0027	302.56
Hammond Place.....	.00313	414.88	No. 16—R. 4.....	.0045	504.94
Haynesville.....	.0092	760.00	No. 17—R. 4.....	.0038	278.96
Hersey.....	.0093	900.00	Total.....		149,452.98
Hodgdon.....	.0087	3,000.00	Cumberland:		
Houlton.....	.0035	13,000.00	Baldwin.....	.0034	1,200.00
Island Falls.....	.002	900.00	Bridgton.....	.003	5,000.00
Limestone.....	.0039	3,250.00	Brunswick.....	.002	11,000.00
Linneus.....	.0069	2,000.00	Cape Elizabeth.....	.0045	7,400.00
Littleton.....	.0052	2,500.00	Casco.....	.0037	1,100.00
Ludlow.....	.0109	1,400.00	Cumberland.....	.0022	2,500.00
Macwahoc Place.....	.00456	300.00	Falmouth.....	.0021	3,700.00
Madawaska.....	.0033	1,400.00	Freeport.....	.002	3,000.00
Mapleton.....	.0059	2,500.00	Gorham.....	.0035	7,500.00
Mars Hill.....	.0063	5,000.00	Gray.....	.0042	2,300.00
Marsadis.....	.0049	1,000.00	Harpeswell.....	.0042	4,200.00

MAINE—Continued.

TABLE 7.—Town revenues applied to town roads and bridges, 1914—Continued.

County and town.	Tax rate per \$1.	Amounts obtained.	County and town.	Tax rate per \$1.	Amounts obtained.
Cumberland—Continued.			Hancock—Continued.		
Harrison.....	\$.0045	\$2,440.00	Sullivan.....	\$.0033	\$1,300.00
Naples.....	.0058	1,750.00	Surry.....	.0042	800.00
New Gloucester.....	.0027	3,000.00	Swans Island.....	.0053	900.00
North Yarmouth.....	.0034	1,100.00	Tremont.....	.0036	1,050.00
Otisfield.....	.0045	1,250.00	Trenton.....	.0049	700.00
Pownal.....	.0034	900.00	Verona.....	.0097	700.00
Raymond.....	.0071	1,900.00	Waltham.....	.0064	520.00
Scarboro.....	.0032	5,500.00	Winter Harbor.....	.0019	1,000.00
Sebago.....	.0065	1,800.00	No. 4 (middle division) Place.....		
Standish.....	.0026	3,300.00	No. 7 (south division).....	.0014	64.59
Windham.....	.0035	4,550.00	No. 8 (south division) Place.....		
Yarmouth.....	.0014	2,250.00	No. 9.....	.0042	102.47
Total.....		78,640.00	No. 10.....	.0106	116.40
Franklin:			No. 10.....	.0055	313.82
Avon.....	.0046	900.00	No. 21 Place.....	.0028	125.00
Coplin Place.....	.0054	600.00	No. 22.....	.0035	154.37
Carthage.....	.0065	1,150.00	No. 28.....	.0013	88.16
Crockerton.....	.0093	904.00	No. 33 Place.....	.0011	50.00
Chester ville.....	.0096	2,200.00	Total.....		61,689.81
Dallas.....	.00302	300.00	Kennebec:		
Eustis.....	.003	1,100.00	Albion.....	.0039	1,500.00
Letter E.....	.0034	207.50	Belgrade.....	.0054	3,200.00
Farmington.....	.0039	8,000.00	Benton.....	.0046	2,500.00
Freeman.....	.0094	1,200.00	Chelsea.....	.0071	1,700.00
Industry.....	.0115	1,500.00	China.....	.0073	4,500.00
Jay.....	.0028	6,000.00	Clinton.....	.0032	2,000.00
Jerusalem Place.....	.0122	1,049.30	Farmingdale.....	.0031	2,100.00
Kingfield.....	.0019	800.00	Fayette.....	.0053	1,200.00
Lang Place.....	.0018	200.00	Litchfield.....	.0031	1,200.00
Madrid.....	.0104	1,300.00	Manchester.....	.0040	1,200.00
New Sharon.....	.0049	2,000.00	Monmouth.....	.0045	3,500.00
New Vineyard.....	.0094	2,000.00	Mount Vernon.....	.0052	1,750.00
Perkins.....	.017	344.00	Oakland.....	.003	3,500.00
Phillips.....	.0037	2,700.00	Pittston.....	.0081	3,500.00
Rangeley.....	.00202	2,300.00	Randolph.....	.004	1,250.00
Rangeley Place.....	.0018	700.00	Readfield.....	.0034	1,800.00
Salem.....	.00637	450.00	Rome.....	.0043	800.00
Sandy River Place.....	.0065	1,100.00	Sidney.....	.0048	2,100.00
Strong.....	.00607	2,000.00	Unity Place.....	.0056	125.00
Temple.....	.00656	1,000.00	Vassalboro.....	.0033	4,000.00
Washington.....	.0184	114.60	Vienna.....	.0070	1,000.00
Weld.....	.0076	2,090.00	Wayne.....	.0051	1,300.00
Wilton.....	.0054	8,000.00	West Gardiner.....	.0028	1,000.00
Wyman.....	.0103	641.00	Windsor.....	.0073	2,000.00
No. 6 (north of Weld).....	.006	550.00	Winslow.....	.0024	6,000.00
Total.....		51,310.40	Winthrop.....	.0036	5,500.00
Hancock:			Total.....		60,225.00
Amherst.....	.0042	350.00	Knox:		
Aurora.....	.0056	300.00	Appleton.....	.0114	2,900.00
Bluehill.....	.0044	3,000.00	Camden.....	.0023	6,250.00
Brooklin.....	.0043	1,000.00	Criehaven Place.....		
Brooksville.....	.0039	1,200.00	Cushing.....	.0051	700.00
Bucksport.....	.0061	5,500.00	Friendship.....	.0034	1,000.00
Castine.....	.0016	1,000.00	Hope.....	.0023	500.00
Cranberry Isles.....	.0022	500.00	Hurricane Isle.....		
Dedham.....	.007	800.00	Matineus Place.....		
Deer Isle.....	.0033	1,500.00	North Haven.....	.0018	800.00
Eastbrook.....	.0040	300.00	Rockport.....	.0022	3,000.00
Eden.....	.0025	18,250.00	St. George.....	.0043	2,177.00
Franklin.....	.0053	1,800.00	South Thomaston.....	.0038	1,800.00
Gouldsboro.....	.0051	2,250.00	Thomaston.....	.0023	2,800.00
Hancock.....	.0056	2,000.00	Union.....	.0072	4,000.00
Isle Au Haut.....	.005	600.00	Vinalhaven.....	.0028	2,500.00
Lamoine.....	.0029	550.00	Warren.....	.0042	3,600.00
Long Island Place.....			Washington.....	.0059	1,600.00
Mariaville.....	.009	600.00	Total.....		33,627.00
Mount Desert.....	.0022	5,000.00	Lincoln:		
Orland.....	.0051	1,500.00	Alna.....	.0055	1,000.00
Otis.....	.0039	200.00	Boothbay.....	.005	3,800.00
Penobscot.....	.006	1,500.00	Boothbay Harbor.....	.0028	3,500.00
Sedgwick.....	.0051	1,205.00	Bremen.....	.0062	965.00
Sorrento.....	.0042	800.00			
Southwest Harbor.....	.0021	1,000.00			
Stonington.....	.0017	1,000.00			

MAINE—Continued.

TABLE 7.—Town revenues applied to town roads and bridges, 1914—Continued.

County and town.	Tax rate per \$1.	Amounts obtained.	County and town.	Tax rate per \$1.	Amounts obtained.
Lincoln—Continued.			Penobscot—Continued.		
Bristol.....	\$0.0034	\$04,000.00	Dexter.....	\$0.0049	\$7,500.00
Damariscotta.....	.0039	1,980.00	Dixmont.....	.0094	2,350.00
Dresden.....	.0051	1,750.00	Drew Place.....	.0037	500.00
Edgecomb.....	.0057	1,200.00	East Millinocket.....	.0029	2,000.00
Jefferson.....	.0030	1,350.00	Edinbury.....	.0032	150.00
Monhegan Place.....	.0012	100.00	Eddington.....	.00612	1,200.00
Newcastle.....	.0041	2,800.00	Endfield.....	.0042	1,500.00
Nobleboro.....	.0049	1,300.00	Etna.....	.0086	1,300.00
Somerville.....	.0125	800.00	Exeter.....	.0046	1,500.00
Southport.....	.0027	1,500.00	Garland.....	.00825	2,500.00
Waldoboro.....	.0046	5,200.00	Glenburn.....	.0027	500.00
Westport.....	.0045	650.00	Grand Falls Place.....	.003	268.31
Whitefield.....	.0041	1,900.00	Greenbush.....	.00729	800.00
Wiscasset.....	.0031	2,050.00	Greenfield.....	.0074	400.00
Total.....		35,845.00	Hampden.....	.00434	3,500.00
Oxford:			Hermion.....	.0052	2,450.00
Albany.....	.0091	1,500.00	Holden.....	.0049	900.00
Andover.....	.0034	1,200.00	Howland.....	.00407	1,200.00
Andover.....			Newport.....	.0038	3,500.00
North surplus.....	.0059	554.88	Hudson.....	.0064	850.00
West surplus.....	.0045	176.45	Kenduskeag.....	.0052	1,000.00
Bethel.....	.0048	5,000.00	Kingman.....	.00218	350.00
Brownfield.....	.0041	1,500.00	Lagrange.....	.0025	800.00
Buckfield.....	.0031	1,500.00	Lakeville Place.....	.0026	400.00
Byron.....	.0091	1,100.00	Lee.....	.0071	1,000.00
Letter C.....	.0022	951.83	Levant.....	.0079	2,000.00
C surplus.....	.0003	50.00	Lincoln.....	.0029	2,500.00
Canton.....	.0058	2,000.00	Lowell.....	.0039	400.00
Denmark.....	.0035	1,500.00	Mattamiscontis.....	.006	169.60
Dixfield.....	.0043	2,500.00	Mattawamkeag.....	.004	650.00
Fryeburg.....	.0026	2,500.00	Maxfield.....	.0074	300.00
Gilead.....	.0036	500.00	Medway.....	.0095	1,000.00
Grafton.....	.0058	1,000.00	Millford.....	.00209	2,000.00
Greenwood.....	.0072	1,500.00	Millinocket.....	.00222	3,500.00
Hanover.....	.0031	300.00	Mount Chase.....	.024	2,000.00
Hartford.....	.0073	2,000.00	Newburg.....	.00425	1,200.00
Hebron.....	.0047	1,200.00	Orono.....	.00159	2,100.00
Hiram.....	.0034	1,500.00	Orrington.....	.0055	2,500.00
Lincoln Place.....	.0011	500.00	Passadumkeag.....	.00357	400.00
Lovell.....	.0056	2,900.00	Patten.....	.00349	2,500.00
Magalloway Place.....	.0054	1,500.00	Plymouth.....	.0083	1,700.00
Mason.....	.0034	300.00	Prentiss.....	.00713	900.00
Mexico.....	.0031	2,200.00	Seboeis Place.....	.0017	171.44
Milton Place.....	.0066	500.00	Springfield.....	.0053	900.00
Newry.....	.0028	800.00	Stacyville Place.....	.008	1,000.00
Norway.....	.0028	4,000.00	Stetson.....	.00758	1,500.00
Oxford.....	.0045	2,500.00	Summit.....	.0035	272.59
Paris.....	.0025	4,000.00	Veazie.....	.0023	775.00
Peru.....	.0095	2,800.00	Webster.....	.006	250.00
Porter.....	.0038	1,000.00	Winn.....	.00303	600.00
Riley.....	.0009	157.40	Woodville.....	.0069	600.00
Roxbury.....	.0057	1,000.00	Letter A, R. 7.....	.0028	264.37
Rumford.....	.0021	10,000.00	No. 1—R. 7.....	.0016	213.66
Stoneham.....	.0035	400.00	No. 2—R. 6.....	.007	115.41
Stow.....	.0046	600.00	No. 2—R. 7.....	.0008	118.08
Summer.....	.0087	2,800.00	Total.....		84,895.46
Sweden.....	.0033	550.00	Piscataquis:		
Upton.....	.0055	850.00	Abbott.....	.0055	1,200.00
Waterford.....	.0068	2,500.00	Atkinson.....	.0099	1,750.00
Woodstock.....	.0061	1,800.00	Barnard.....	.00576	294.51
Total.....		73,690.56	Blanchard.....	.00355	400.00
Penobscot:			Bowerbank Place.....	.00132	150.00
Alton.....	.00547	500.00	Brownville.....	.00416	2,450.00
Argyle.....	.00442	300.00	Dover.....	.00452	5,000.00
Bradford.....	.00418	1,200.00	Elliottsville Place.....	.0028	399.70
Bradley.....	.0011	250.00	Foxcroft.....	.0051	5,250.00
Burlington.....	.0019	350.00	Greenville.....	.00234	1,500.00
Carmel.....	.00378	1,200.00	Guilford.....	.00253	2,000.00
Carroll.....	.0069	1,000.00	Kingsbury Place.....	.0125	1,200.00
Charleston.....	.0086	2,700.00	Lake View Place.....	.0006	114.26
Chester.....	.0061	500.00	Lily Bay Place.....	.0025	450.00
Clifton.....	.0062	400.00	Medford.....	.00587	800.00
Corinna.....	.0067	3,477.00	Milo.....	.0029	3,850.00
Corinth.....	.00405	2,000.00	Monson.....	.00568	2,000.00
			Orneville.....	.00555	700.00
			Parkman.....	.00856	2,000.00

MAINE—Continued.

TABLE 7.—Town revenues applied to town roads and bridges, 1914—Continued.

County and town.	Tax rate per \$1.	Amounts obtained.	County and town.	Tax rate per \$1.	Amounts obtained.
Piscataquis—Continued.			Waldo—Continued.		
Sangerville.....	\$0.00535	\$3,000.00	Islesboro.....	\$0.002	\$2,000.00
Sebec.....	.007	1,500.00	Jackson.....	.01	1,500.00
Shirley.....	.00806	1,000.00	Knox.....	.0061	1,200.00
Wellington.....	.0136	2,000.00	Liberty.....	.0095	2,000.00
Williamsburg.....	.00702	400.00	Lincolnville.....	.009	2,950.00
Willimantic.....	.0056	550.00	Monroe.....	.0093	2,500.00
Total.....		39,958.47	Montville.....	.0082	2,500.00
Sagadahoc:			Morrill.....	.0078	1,000.00
Arrowsic.....	.0045	275.00	Palermo.....	.0071	1,600.00
Bowdoin.....	.006	1,980.00	Northport.....	.0038	1,500.00
Bowdoinham.....	.00232	1,300.00	Prospect.....	.0104	1,800.00
Georgetown.....	.00292	950.00	Searsmont.....	.0072	2,500.00
Perkins.....	.0014	50.00	Searsport.....	.0031	2,500.00
Phillipsburg.....	.00592	2,600.00	Stockton Springs.....	.0024	1,200.00
Richmond.....	.00225	2,300.00	Swanville.....	.0089	1,500.00
Topsham.....	.0051	8,000.00	Thorndike.....	.0052	1,200.00
West Bath.....	.0067	1,400.00	Troy.....	.0075	2,000.00
Woolwich.....	.0053	1,800.00	Unity.....	.0066	2,500.00
Total.....		20,655.00	Waldo.....	.0055	800.00
Somerset:			Winterport.....	.0043	2,500.00
Anson.....	.00369	3,000.00	Total.....		42,850.00
Athens.....	.00622	2,000.00	Washington:		
Bald Mountain.....	.0007	110.01	Addison.....	.0046	1,000.00
Bigelow.....	.00614	479.36	Alexander.....	.0143	1,000.00
Bingham.....	.00409	2,000.00	Baileyville.....	.00228	3,500.00
Brighton.....	.0158	1,600.00	Boring.....	.00428	450.00
Cambridge.....	.0088	1,200.00	Beddington.....	.0073	225.00
Canaan.....	.0046	1,500.00	Brookton.....	.00426	310.00
Carratunk.....	.00536	700.00	Centerville.....	.00452	325.00
Carrying Place.....	.00125	154.10	Charlotte.....	.00735	650.00
Concord.....	.00936	900.00	Cherryfield.....	.00524	2,300.00
Cornville.....	.00429	1,400.00	Codyville Place.....	.00619	524.23
Dead River Place.....	.00504	500.00	Columbia.....	.006	800.00
Dennistown.....	.0036	478.00	Columbia Falls.....	.0037	600.00
Detroit.....	.00488	800.00	Cooper.....	.00911	500.00
Emden.....	.0069	2,000.00	Crawford.....	.0058	400.00
Fairfield.....	.00273	5,000.00	Cutler.....	.0088	1,000.00
Flagstaff.....	.00488	440.00	Danforth.....	.0052	2,500.00
Harmony.....	.0077	2,150.00	Deblois.....	.0042	100.00
Hartland.....	.00406	2,200.00	Dennysville.....	.00246	350.00
Highland Place.....	.00605	600.00	East Machias.....	.0038	1,500.00
Jackman.....	.0054	1,200.00	Edmonds.....	.0089	775.00
Johnson Mountain.....	.0081	653.84	Forest City.....	.003	50.00
Lexington Place.....	.00705	700.00	Grand Lake Stream Place.....	.00336	400.00
Madison.....	.00303	7,000.00	Harrington.....	.00566	1,400.00
Mayfield.....	.00734	771.54	Jonesboro.....	.00536	600.00
Maxie Gore.....	.00367	856.12	Jonesport.....	.0018	1,000.00
Mercer.....	.0098	1,700.00	Kossuth.....	.00474	576.00
Moose River Place.....	.00218	400.00	Lamber Lake.....	.0074	693.00
Moscow.....	.00714	1,300.00	Lukes.....	.0019	400.00
New Portland.....	.00644	1,800.00	Machias.....	.0036	3,000.00
Norridgewock.....	.00698	5,135.00	Machiasport.....	.0051	1,000.00
Palmyra.....	.0115	4,200.00	Marion.....	.0079	400.00
Parlin.....	.00316	420.00	Marshfield.....	.0073	450.00
Pittsfield.....	.00209	3,500.00	Meddybemps.....	.00442	150.00
Pleasant Ridge Place.....	.0109	586.46	Milbridge.....	.0033	1,500.00
Ripley.....	.00921	1,500.00	Northfield.....	.0055	300.00
Sandy Bay.....	.0068	701.84	Pembroke.....	.00314	1,000.00
St. Albans.....	.0076	3,250.00	Perry.....	.0059	1,250.00
Skowhegan.....	.00256	10,500.00	Princeton.....	.0043	1,350.00
Smithfield.....	.00555	1,000.00	Robbinston.....	.00332	500.00
Solon.....	.0047	2,000.00	Roque Bluffs.....	.0066	200.00
Starks.....	.0097	1,925.00	Steuben.....	.0071	1,500.00
The Forks Place.....	.00847	841.00	Talmage.....	.0095	500.00
West Forks Place.....	.0058	790.41	Topsfield.....	.011	1,400.00
Total.....		81,942.68	Trescott.....	.0098	650.00
Waldo:			Vanceboro.....	.00201	400.00
Belmont.....	.00736	800.00	Waite.....	.0063	300.00
Brooks.....	.00517	1,600.00	Wesley.....	.00468	300.00
Burham.....	.0028	700.00	Whiting.....	.00656	700.00
Frankfort.....	.0048	1,500.00	Whitneyville.....	.0065	445.00
Freedom.....	.0056	1,000.00	No. 8—R. 3.....	.00259	250.00
			No. 8—R. 4.....	.00779	400.00
			No. 10—R. 3.....	.00534	436.38
			No. 14 Place.....	.0054	300.00

MAINE—Continued.

TABLE 7.—Town revenues applied to town roads and bridges, 1914—Continued.

County and town.	Tax rate per \$1.	Amounts obtained.	County and town.	Tax rate per \$1.	Amounts obtained.
Washington—Continued.			York—Continued.		
No. 18, eastern division.	\$0.00875	\$386.40	Kennebunk.....	\$0.00301	\$7,500.00
No. 19, eastern division.	.00416	276.00	Kennebunkport.....	.003	5,000.00
No. 21 Place.....			Kittery.....	.0038	4,000.00
No. 24, middle division.	.00664	330.00	Lebanon.....	.0063	3,100.00
No. 26, eastern division.	.00083	54.40	Limerick.....	.0029	1,500.00
No. 27, eastern division.	.0031	233.00	Limington.....	.0075	3,000.00
No. 29, middle division.	.00664	440.00	Lyman.....	.0026	1,000.00
No. 30, middle division.	.0031	200.40	Newfield.....	.0051	1,200.00
No. 31, middle division.	.00316	220.40	North Berwick.....	.0042	3,400.00
Total.....		44,950.21	Old Orchard.....	.0031	4,000.00
York:			Parsonsfield.....	.0060	3,000.00
Acton.....	.0038	1,000.00	Sanford.....	.0021	9,550.00
Alfred.....	.0038	1,500.00	Shapleigh.....	.0037	1,000.00
Berwick.....	.0037	3,800.00	South Berwick.....	.0025	3,000.00
Buxton.....	.00313	3,700.00	Waterboro.....	.0052	2,500.00
Cornish.....	.0038	1,500.00	Wells.....	.0026	3,500.00
Dayton.....	.0065	1,500.00	York.....	.0034	10,954.00
Eliot.....	.00138	2,000.00	Total.....		86,204.00
Hollis.....	.0041	4,000.00	Grand total.....		978,786.57

NEW HAMPSHIRE.

TABLE 8.—Revenue applied to roads and bridges, 1914.

County and town.	Amount appropriated.	County and town.	Amount appropriated.	County and town.	Amount appropriated.
Belknap:		Cheshire—Continued.		Grafton:	
Alton.....	\$8,185.44	Marlboro.....	\$2,500.00	Alexandria.....	\$2,446.17
Barnstead.....	9,997.50	Marlow.....	1,420.82	Ashland.....	2,800.00
Belmont.....	4,000.00	Nelson.....	1,500.00	Bath.....	3,000.00
Center Harbor.....	3,100.00	Richmond.....	2,735.84	Benton.....	745.00
Gilford.....	3,957.00	Rindge.....	4,100.00	Bethlehem.....	6,000.00
Gilmanton.....	3,409.50	Roxbury.....	1,126.00	Bridgewater.....	1,641.00
Meredith.....	2,444.00	Stoddard.....	1,475.00	Bristol.....	6,399.00
New Hampton.....	3,484.00	Sullivan.....	1,200.00	Campton.....	3,000.00
Sanbornton.....	3,600.00	Surry.....	1,100.00	Canaan.....	5,000.00
Tilton.....	6,024.50	Swanzy.....	6,648.50	Dorchester.....	1,500.00
Total.....	48,201.94	Troy.....	3,000.00	Easton.....	452.62
Carroll:		Walpole.....	5,000.00	Ellsworth.....	600.00
Albany.....	1,800.00	Westmoreland.....	4,120.16	Enfield.....	5,000.00
Bartlett.....	4,300.00	Winchester.....	4,846.08	Franconia.....	3,767.15
Brookfield.....	765.00	Total.....	90,823.68	Grafton.....	2,500.00
Chatham.....	952.00	Coos:		Groton.....	1,500.00
Conway.....	6,681.36	Carroll.....	2,600.00	Hanover Village.....	6,200.19
Eaton.....	1,456.50	Clarksville.....	2,800.00	Haverhill.....	10,000.00
Effingham.....	1,800.00	Colebrook.....	5,250.00	Hanover.....	9,053.00
Freedom.....	1,000.00	Columbia.....	1,747.29	Hebron.....	800.00
Jackson.....	2,100.00	Dalton.....	2,490.00	Holderness.....	6,875.00
Madison.....	1,650.00	Dummer.....	2,400.00	Landaff.....	1,132.91
Moultonboro.....	6,482.00	Errel.....	5,237.00	Lebanon.....	9,000.00
Ossipee.....	5,000.00	Gorham.....	8,200.00	Lincoln.....	1,500.00
Sandwich.....	3,000.00	Jefferson.....	12,272.32	Lisbon.....	10,000.00
Tamworth.....	3,000.00	Lancaster.....	9,677.62	Littleton.....	4,200.00
Tuftsboro.....	2,427.00	Milan.....	3,100.00	Lyme.....	1,500.00
Wakefield.....	4,800.00	Northumberland.....	3,200.00	Monroe.....	1,273.55
Wolfeboro.....	12,194.67	Pittsburg.....	3,600.00	Orange.....	600.00
Total.....	59,408.53	Randolph.....	1,086.58	Orford.....	2,637.50
Cheshire:		Shelburne.....	1,000.00	Piermont.....	3,025.00
Alstead.....	2,600.00	Stark.....	2,000.00	Plymouth.....	9,909.50
Chesterfield.....	4,553.50	Stewartstown.....	3,277.71	Rumney.....	1,506.22
Dublin.....	11,650.00	Stratford.....	3,235.00	Thornton.....	2,361.10
Fitzwilliam.....	4,500.00	Wentworth Loca- tion.....	1,060.00	Warren.....	2,300.00
Gilsom.....	1,000.00	Whitefield.....	4,390.00	Waterville.....	1,000.00
Harrisville.....	3,550.00	Total.....	78,623.52	Wentworth.....	1,336.07
Hinsdale.....	14,462.00			Woodstock.....	3,000.00
Jaffrey.....	7,735.78			Total.....	138,560.98

NEW HAMPSHIRE—Continued.

TABLE 8.—Revenue applied to roads and bridges, 1914—Continued.

County and town.	Amount appropriated.	County and town.	Amount appropriated.	County and town.	Amount appropriated.
Hillsborough:		Merrimack—Contd.		Rockingham—Contd.	
Amherst.....	\$3,200.00	Hopkinton.....	\$5,389.51	Salem.....	\$9,125.00
Antrim.....	4,000.00	Loudon.....	5,114.37	Sandown.....	1,000.00
Bedford.....	2,584.31	Newbury.....	3,800.00	Seabrook.....	1,380.45
Bennington.....	1,956.00	New London.....	3,150.00	South Hampton.....	743.77
Brookline.....	1,233.76	Northfield.....	3,900.81	Stratham.....	3,200.00
Deering.....	1,700.00	Pembroke.....	2,493.75	Windham.....	3,000.00
Francestown.....	1,800.00	Pittsfield.....	4,687.00		
Greenfield.....	2,100.00	Salisbury.....	2,492.00	Total.....	111,850.64
Goffstown.....	4,400.00	Sutton.....	3,700.00		
Greenville.....	2,099.50	Warner.....	2,500.00	Strafford:	
Hancock.....	1,850.00	Webster.....	1,894.50	Barrington.....	3,000.00
Hillsboro.....	7,674.12	Wilmot.....	3,161.83	Durham.....	2,500.00
Hollis.....	2,175.92			Farmington.....	10,503.43
Hudson.....	3,683.40	Total.....	77,709.91	Lee.....	956.85
Litchfield.....	977.14			Madbury.....	672.00
Lyndeboro.....	2,977.50	Rockingham:		Middleton.....	583.36
Mason.....	1,478.50	Atkinson.....	910.16	Milton.....	7,871.24
Merrimack.....	4,300.00	Auburn.....	3,000.00	New Durham.....	1,768.50
Milford.....	10,200.00	Brentwood.....	3,000.00	Rollinsford.....	2,700.00
Mont Vernon.....	1,443.94	Candia.....	1,539.71	Strafford.....	3,774.00
New Boston.....	3,900.00	Chester.....	2,300.00		
New Ipswich.....	2,944.12	Danville.....	1,770.00	Total.....	34,329.38
Pelham.....	2,300.00	Deerfield.....	2,200.00		
Peterboro.....	14,500.00	Derry.....	11,000.00	Sullivan:	
Sharon.....	1,849.00	East Kingston.....	701.00	Acworth.....	2,500.00
Temple.....	1,585.00	Epping.....	4,500.00	Charlestown.....	4,727.03
Weare.....	4,500.00	Exeter.....	10,133.36	Claremont.....	9,557.00
Wilton.....	5,279.89	Fremont.....	1,700.00	Cornish.....	2,739.08
Windser.....	292.00	Greenland.....	2,050.00	Croydon.....	1,200.00
Total.....	98,984.10	Hampstead.....	3,912.29	Goshen.....	1,662.50
		Hampton.....	5,387.00	Graham.....	1,725.00
Merrimack:		Hampton Falls.....	1,862.00	Langdon.....	590.00
Allenstown.....	1,759.00	Kensington.....	742.54	Lempster.....	1,342.95
Andover.....	2,197.79	Kingston.....	1,573.94	Newport.....	8,700.00
Boscawen.....	2,725.00	Londonderry.....	4,000.00	Plainfield.....	2,303.26
Bow.....	3,046.50	New Castle.....	3,196.83	Springfield.....	2,800.00
Bradford.....	3,611.50	Newfields.....	549.38	Sunapee.....	7,058.61
Canterbury.....	3,347.00	Newington.....	1,783.50	Unity.....	1,393.00
Chichester.....	2,500.00	New Market.....	4,360.00	Washington.....	1,500.00
Danbury.....	2,000.00	Newton.....	1,480.30		
Dunbarton.....	1,600.00	North Hampton.....	3,470.00	Total.....	49,798.43
Epsom.....	3,000.00	Northwood.....	3,100.00		
Henniker.....	4,109.35	Nottingham.....	1,766.16	Grand total for	
Hill.....	1,500.00	Plaistow.....	3,713.25	State.....	788,291.11
Hookset.....	4,000.00	Raymond.....	3,500.00		
		Rye.....	4,200.00		

VERMONT.

TABLE 9.—Town revenues applied to town and State aid roads and bridges, 1914.

County and town.	Total town revenues applied to town and State-aid roads.	Town tax for town roads.		Amounts raised from 5 per cent State road tax.	Amounts raised by towns for State-aid roads.	Resurfacing of town roads, amount raised.
		Rate. ¹	Amount obtained.			
Addison:						
Addison.....	\$3,043.14	20	\$1,624.36	\$418.78	\$1,000.00	.....
Bridport.....	2,808.94	20	1,647.15	411.79	750.00	.....
Bristol.....	4,117.74	20	2,473.58	644.16	1,000.00	.....
Cornwall.....	1,958.73	20	1,158.99	299.74	500.00	.....
Ferrisburg.....	3,263.93	20	2,217.14	546.79	500.00	.....
Goshen.....	602.93	45	452.64	50.29	100.00	.....
Granville.....	1,619.10	20	504.95	114.15	1,000.00	.....
Hancock.....	787.45	25	489.54	97.91	200.00	.....
Leicester.....	1,724.26	40	1,028.00	256.26	300.00	\$140.00
Lincoln.....	1,104.03	20	881.51	222.52	.....	.....

¹ The rate is expressed in per cent of the grand list, which is found by taking 1 per cent of the assessed valuation of all taxable property.

VERMONT—Continued.

TABLE 9.—Town revenues applied to town and State aid roads and bridges, 1914—Contd.

County and town.	Total town revenues applied to town and State-aid roads.	Town tax for town roads.		Amounts raised from 5 per cent State road tax.	Amounts raised by towns for State-aid roads.	Resurfacing of town roads, amount raised.
		Rate.	Amount obtained.			
Addison—Continued.						
Middlebury.....	\$5,133.43	32	\$2,420.59	\$1,212.84	\$1,500.00	.....
Monkton.....	1,194.06	20	957.72	236.34	.....	.....
New Haven.....	3,096.67	25	2,210.06	443.48	443.13	.....
Orwell.....	8,459.46	50	5,041.98	672.69	1,000.00	\$1,744.79
Panton.....	1,658.60	20	661.82	166.60	750.00	80.18
Ripton.....	1,084.04	20	627.60	156.44	300.00	.....
Salisbury.....	2,095.69	20	1,309.84	285.85	500.00	.....
Shoreham.....	3,047.16	20	1,641.37	405.79	1,000.00	.....
Starksboro.....	2,371.71	20	874.00	528.54	500.00	469.17
Waltham.....	693.84	20	381.72	112.12	200.00	.....
Weybridge.....	1,451.09	20	847.69	203.40	400.00	.....
Whiting.....	1,075.23	20	452.24	122.99	500.00	.....
Total.....	52,391.23	.....	29,904.49	7,609.47	12,443.13	2,434.14
Bennington:						
Arlington.....	1,868.39	20	1,234.71	333.68	300.00	.....
Bennington.....	3,790.49	20	.....	2,790.49	1,000.00	.....
Dorset.....	2,423.10	20	1,557.66	365.44	500.00	.....
Glastenbury.....	287.76	30	143.88	23.98	119.90	.....
Landgrove.....	225.87	30	73.71	152.16	.....	.....
Peru.....	1,526.18	50	934.44	91.74	500.00	.....
Pownal.....	2,937.88	20	1,950.30	487.58	500.00	.....
Readsboro.....	4,503.49	50	3,191.92	311.57	1,000.00	.....
Rupert.....	3,691.75	40	2,441.56	400.41	609.78	240.00
Sandgate.....	664.93	35	583.93	81.00	.....	.....
Searsburg.....	963.51	70	639.96	49.28	274.27	.....
Shaftsbury.....	2,712.40	30	2,254.63	357.77	100.00	.....
Stamford.....	1,391.83	20	800.00	141.83	350.00	100.00
Sunderland.....	1,138.62	20	804.77	183.85	150.00	.....
Winhall.....	1,186.18	30	759.58	126.60	300.00	.....
Woodford.....	1,490.00	50	900.00	90.00	500.00	.....
Total.....	30,802.38	.....	18,271.05	5,987.38	6,203.95	340.00
Caledonia:						
Barnet.....	6,424.30	35	4,746.26	678.04	1,000.00	.....
Burke.....	845.11	20	.....	345.11	500.00	.....
Danville.....	4,693.89	40	3,727.91	465.98	500.00	.....
Groton.....	2,912.69	40	2,144.62	268.07	500.00	.....
Hardwick.....	1,859.30	.....	.....	859.30	1,000.00	.....
Kirby.....	1,465.49	50	1,105.49	110.00	250.00	.....
Lyndon.....	5,167.16	35	3,260.44	696.72	1,000.00	210.00
Newark.....	1,116.47	40	994.11	122.36	.....	.....
Peacham.....	3,622.81	50	2,838.92	283.89	500.00	.....
Ryeate.....	4,083.32	25	2,658.84	424.48	1,000.00	.....
Sheffield.....	2,358.87	65	2,005.55	153.32	200.00	.....
Stannard.....	746.95	60	502.80	144.15	100.00	.....
Sutton.....	1,983.58	20	754.50	584.60	300.00	344.48
Walden.....	1,770.96	40	1,389.97	180.99	200.00	.....
Waterford.....	762.48	.....	.....	262.48	500.00	.....
Wheelock.....	1,682.19	40	1,241.37	40.82	400.00	.....
Total.....	41,495.57	.....	27,370.78	5,620.31	7,950.00	554.48
Chittenden:						
Bolton.....	1,023.00	30	672.00	117.00	234.00	.....
Charlotte.....	2,620.40	20	2,046.79	573.61	.....	.....
Colchester.....	3,782.98	20	1,382.28	1,400.70	1,000.00	.....
Essex.....	3,041.92	20	1,363.32	678.60	1,000.00	.....
Hinesburg.....	2,907.87	20	1,502.69	405.18	1,000.00	.....
Huntington.....	1,535.85	25	1,065.18	213.03	.....	257.64
Jericho.....	2,661.37	20	1,929.10	482.27	250.00	.....
Milton.....	3,393.34	20	1,927.11	466.23	1,000.00	.....
Richmond.....	3,006.32	20	1,814.14	442.18	750.00	.....
St. George.....	205.67	25	170.75	34.92	.....	.....
Shelburne.....	2,927.29	20	2,086.97	320.33	300.00	219.99
South Burlington.....	2,736.34	20	1,389.02	347.32	1,000.00	.....
Underhill.....	1,882.56	20	1,266.05	316.51	300.00	.....
Westford.....	1,624.18	20	1,062.97	261.21	300.00	.....
Williston.....	2,531.34	20	1,625.07	406.27	500.00	.....
Total.....	35,880.43	.....	21,303.44	6,465.36	7,634.00	477.63

VERMONT—Continued.

TABLE 9.—Town revenues applied to town and State aid roads and bridges, 1914—Contd.

County and town.	Total town revenues applied to town and State-aid roads.	Town tax for town roads.		Amounts raised from 5 per cent State road tax.	Amounts raised by towns for State-aid roads.	Resurfacing of town roads, amount raised.
		Rate.	Amount obtained.			
Essex:						
Bloomfield.....	\$1,955.55	26	\$1,011.11	\$194.44	\$750.00	.....
Brighton.....	3,618.50	8	2,026.10	506.52	400.00	\$685.88
Brunswick.....	885.21	20	314.86	70.35	500.00	.....
Canaan.....	1,729.79	20	1,143.83	285.96	.....	300.00
Concord.....	4,164.34	60	3,124.20	520.07	520.07	.....
East Haven.....	438.90	20	315.75	93.15	.....	.....
Granby.....	639.71	30	440.67	74.04	125.00	.....
Guildhall.....	1,197.37	20	562.23	135.14	500.00	.....
Lemington.....	904.44	25	336.22	68.22	500.00	.....
Lunenburg.....	4,701.00	43	2,000.00	504.00	1,000.00	1,200.00
Maidstone.....	1,657.21	20	808.98	148.23	700.00	.....
Norton.....	1,680.62	20	523.27	110.31	1,046.54	.....
Victory.....	407.70	25	339.96	67.74	.....	.....
Total.....	23,983.34	.....	12,977.18	2,778.67	6,041.61	2,185.88
Franklin:						
Bakersfield.....	2,032.48	20	953.64	247.49	750.00	81.35
Berkshire.....	2,785.30	20	1,591.60	397.90	795.80	.....
Enosburg.....	2,911.72	20	1,251.42	660.30	1,000.00	.....
Fairfax.....	2,974.42	20	1,591.77	632.65	750.00	.....
Fairfield.....	3,539.21	20	2,019.61	519.60	1,000.00	.....
Fletcher.....	638.05	25	465.05	173.00	.....	.....
Franklin.....	2,236.14	25	1,750.79	345.29	140.00	.....
Georgia.....	2,542.11	20	1,241.49	600.62	500.00	200.00
Highgate.....	2,097.27	20	1,677.82	419.45	.....	.....
Montgomery.....	3,627.90	30	2,470.20	407.70	750.00	.....
Richford.....	3,899.06	25	1,953.33	745.73	1,000.00	200.00
St. Albans.....	3,964.79	20	1,759.73	486.28	1,000.00	718.78
Sheldon.....	3,388.32	20	1,750.66	437.66	1,000.00	200.00
Swanton.....	3,592.41	20	2,021.53	820.88	750.00	.....
Total.....	40,229.18	.....	22,498.64	6,894.55	9,435.86	1,400.13
Grand Isle:						
Alburg.....	1,775.73	20	1,424.13	351.60	.....	.....
Grand Isle.....	1,324.10	20	817.84	206.26	300.00	.....
Isle La Motte.....	896.90	20	399.26	97.64	400.00	.....
North Hero.....	964.58	20	541.52	138.36	100.00	184.70
South Hero.....	1,368.24	20	694.59	173.65	500.00	.....
Total.....	6,329.55	.....	3,877.34	967.51	1,300.00	184.70
Lamoille:						
Belvidere.....	1,022.38	20	790.20	107.18	125.00	.....
Cambridge.....	4,344.00	25	2,791.00	553.00	1,000.00	.....
Eden.....	1,713.52	35	1,236.83	176.69	300.00	.....
Elmore.....	1,089.41	35	953.24	136.17	.....	.....
Hyde Park.....	3,520.27	25	2,516.89	503.38	500.00	.....
Johnson.....	2,011.00	20	1,608.80	402.20	.....	.....
Morristown.....	5,087.12	35	2,043.56	2,043.56	1,000.00	.....
Stowe.....	3,144.78	30	2,100.00	544.78	500.00	.....
Waterville.....	561.42	20	447.54	113.88	.....	.....
Wolcott.....	2,731.53	25	1,347.83	544.56	269.57	569.57
Total.....	25,225.43	.....	15,835.89	5,125.40	3,694.57	569.57
Orange:						
Bradford.....	2,582.93	20	1,600.00	502.93	750.00	.....
Braintree.....	1,576.51	25	980.43	196.08	400.00	.....
Brookfield.....	2,527.62	25	1,601.62	273.73	500.00	152.27
Chelsea.....	2,148.14	20	1,027.66	520.48	600.00	.....
Corinth.....	1,722.67	30	1,305.15	217.52	200.00	.....
Fairlee.....	1,410.22	20	800.93	209.29	250.00	150.00
Newbury.....	5,787.58	40	4,000.00	787.58	1,000.00	.....
Orange.....	2,441.34	50	1,764.89	174.75	300.00	201.70
Randolph.....	4,223.85	20	1,991.07	1,232.78	1,000.00	.....
Strafford.....	1,924.04	30	1,211.98	212.06	500.00	.....
Thetford.....	3,294.81	30	1,760.00	784.81	750.00	.....
Topsham.....	1,057.20	20	845.15	212.05	.....	.....
Tunbridge.....	2,457.17	30	1,634.72	272.45	400.00	150.00
Vershire.....	1,917.55	35	781.89	772.01	223.65	140.00
Washington.....	1,909.18	25	1,061.57	209.40	638.21	.....
West Fairlee.....	845.07	25	468.58	176.49	200.00	.....
Williamstown.....	5,224.25	20	1,798.32	500.00	1,882.82	1,043.11
Total.....	43,320.13	.....	24,633.96	7,254.41	9,594.68	1,837.08

VERMONT—Continued.

TABLE 9.—Town revenues applied to town and State aid roads and bridges, 1914—Contd.

County and town.	Total town revenues applied to town and State-aid roads.	Town tax for town roads.		Amounts raised from 5 per cent State road tax.	Amounts raised by towns for State-aid roads.	Resurfacing of town roads, amount raised.
		Rate.	Amount obtained.			
Orleans:						
Albany.....	\$1,827.26	20	\$1,044.15	\$261.05	\$522.06	.....
Barton.....	6,000.72	45	3,600.00	1,078.22	1,000.00	\$322.50
Brownington.....	1,509.74	20	864.00	345.74	300.00	.....
Charleston.....	2,535.19	30	1,748.91	286.28	500.00	.....
Coventry.....	2,199.25	35	1,486.99	212.26	500.00	.....
Craftsbury.....	2,244.59	20	1,296.12	324.04	518.44	105.99
Derby.....	3,640.04	20	1,400.00	1,240.04	1,000.00	.....
Glover.....	10,002.54	25	9,339.33	263.21	400.00	.....
Greensboro.....	2,904.21	20	1,287.58	616.63	1,000.00	.....
Holland.....	1,532.25	30	1,141.03	191.22	200.00	.....
Irasburg.....	3,239.25	30	1,919.35	319.90	1,000.00	.....
Jay.....	655.79	30	557.96	97.83	.....	.....
Lowell.....	3,027.27	40	2,205.48	270.42	551.37	.....
Morgan.....	1,262.61	30	841.74	140.29	280.58	.....
Newport.....	5,615.02	30	3,300.00	1,315.02	1,000.00	.....
Troy.....	3,038.24	30	1,520.28	472.49	800.00	245.47
Westfield.....	1,031.39	35	902.03	129.36	.....	.....
Westmore.....	886.86	25	586.78	100.08	200.00	.....
Total.....	53,152.22	.....	35,041.73	7,664.08	9,772.45	673.96
Rutland:						
Benson.....	2,447.17	20	1,700.28	296.89	300.00	150.00
Brandon.....	5,303.09	20	3,842.47	960.62	500.00	.....
Castleton.....	3,321.65	20	1,857.32	464.33	500.00	500.00
Chittenden.....	1,747.30	30	1,023.98	323.32	400.00	.....
Clarendon.....	2,048.21	20	1,229.64	318.57	500.00	.....
Danby.....	2,568.05	25	1,812.18	378.07	377.80	.....
Fair Haven.....	4,311.13	20	3,000.00	811.13	500.00	.....
Hubbarton.....	1,047.24	20	472.59	118.15	300.00	156.50
Ira.....	783.08	25	643.68	89.40	.....	50.00
Mendon.....	1,132.99	20	584.53	256.26	292.20	.....
Middletown Springs.....	1,416.12	20	983.49	232.63	200.00	.....
Mount Holly.....	1,726.47	25	1,166.53	233.31	326.63	.....
Mount Tabor.....	471.33	25	394.34	76.99	.....	.....
Pawlet.....	3,200.79	20	2,169.15	531.64	500.00	.....
Pittsfield.....	972.17	30	654.00	168.17	150.00	.....
Pittsford.....	5,422.77	20	3,229.02	908.75	1,000.00	285.00
Poultney.....	5,339.04	20	3,047.65	767.43	1,523.96	.....
Proctor.....	2,548.80	20	229.67	1,319.13	1,000.00	.....
Rutland.....	3,213.65	20	1,683.73	264.27	1,000.00	265.65
Sherburne.....	763.34	20	518.32	115.02	130.00	.....
Shrewsbury.....	1,017.17	20	408.34	608.83	.....	.....
Sudbury.....	1,786.44	30	1,062.14	296.30	200.00	228.00
Tinmouth.....	1,005.18	25	670.98	154.20	200.00	.....
Wallingford.....	5,642.60	20	4,114.08	528.52	1,000.00	.....
Wells.....	1,500.28	20	795.19	205.09	500.00	.....
West Haven.....	1,408.57	20	694.10	280.29	200.00	234.18
West Rutland.....	945.54	20	.....	945.54	.....	.....
Total.....	63,090.17	.....	37,987.40	11,632.85	11,600.59	1,869.33
Washington:						
Barre.....	7,262.00	20	4,200.00	650.00	1,000.00	1,406.00
Berlin.....	2,676.43	31	2,324.74	351.69	.....	.....
Cabot.....	2,726.65	45	2,113.44	313.21	300.00	.....
Calais.....	2,900.13	35	1,808.00	258.28	545.43	288.42
Duxbury.....	715.52	50	.....	215.52	500.00	.....
East Montpelier.....	5,246.43	50	3,519.50	616.63	1,000.00	110.30
Fayston.....	1,392.75	30	932.49	160.26	300.00	.....
Marshfield.....	2,846.03	45	2,291.43	254.60	300.00	.....
Middlesex.....	2,234.15	30	1,519.35	264.80	450.00	.....
Moretown.....	500.00	.....	.....	.....	500.00	.....
Northfield.....	3,548.57	30	2,400.00	898.57	250.00	.....
Plainfield.....	1,431.56	25	1,192.97	238.59	.....	.....
Roxbury.....	2,059.87	40	1,475.44	184.43	400.00	.....
Waitsfield.....	1,652.06	20	1,001.65	250.41	400.00	.....
Warren.....	1,624.01	30	1,182.08	191.93	250.00	.....
Waterbury.....	4,839.44	20	3,271.55	817.89	750.00	.....
Woodbury.....	2,148.25	40	1,458.36	189.89	500.00	.....
Worcester.....	1,354.47	25	846.54	169.31	338.62	.....
Total.....	47,158.32	.....	31,537.54	6,032.01	7,784.05	1,804.72

VERMONT—Continued.

TABLE 9.—Town revenues applied to town and State aid roads and bridges, 1914—Contd.

County and town.	Total town revenues applied to town and State-aid roads.	Town tax for town roads.		Amounts raised from 5 per cent State road tax.	Amounts raised by towns for State-aid roads.	Resurfacing of town roads, amount raised.
		Rate.	Amount obtained.			
Windham:						
Athens.....	\$546.43	25	\$250.25	\$176.18	-----	\$120.00
Brattleboro.....	23,631.02	25	18,942.12	3,688.90	\$1,000.00	-----
Brookline.....	429.12	25	201.09	152.16	75.87	-----
Dover.....	1,308.88	45	1,169.10	139.78	-----	-----
Dummerston.....	1,315.11	25	1,094.62	220.49	-----	-----
Grafton.....	1,274.87	30	1,092.75	182.12	-----	-----
Guilford.....	1,814.53	30	1,209.35	201.56	403.62	-----
Halifax.....	1,589.35	50	1,256.33	133.02	200.00	-----
Jamaica.....	1,781.67	40	1,361.49	170.18	250.00	-----
Londonderry.....	2,891.84	30	1,618.56	273.28	1,000.00	-----
Marlboro.....	1,210.70	40	898.40	112.30	200.00	-----
Newfane.....	2,842.20	45	2,107.98	234.22	500.00	-----
Putney.....	2,305.54	25	1,506.58	298.96	500.00	-----
Rockingham.....	5,968.74	20	2,000.00	2,968.74	1,000.00	-----
Somerset.....	1,007.08	50	743.62	113.46	150.00	-----
Stratton.....	885.60	40	696.78	88.82	100.00	-----
Townshend.....	2,362.68	30	1,389.38	223.30	750.00	-----
Vernon.....	1,625.21	25	941.75	183.46	500.00	-----
Wardsboro.....	1,616.10	55	1,295.70	120.40	200.00	-----
Westminster.....	2,950.02	25	2,204.87	445.15	300.00	-----
Whitingham.....	3,007.68	40	1,784.74	222.94	1,000.00	-----
Wilmington.....	3,305.15	25	2,337.63	467.52	500.00	-----
Windham.....	1,130.79	40	737.88	92.91	300.00	-----
Total.....	66,800.31	-----	46,840.97	10,909.85	8,929.49	120.00
Windsor:						
Andover.....	1,214.11	50	909.00	105.11	200.00	-----
Baltimore.....	19.70	35	-----	19.70	-----	-----
Barnard.....	1,803.78	35	1,290.59	213.19	300.00	-----
Bethel.....	4,688.79	20	3,074.00	614.79	1,000.00	-----
Bridgewater.....	2,031.34	25	1,279.57	251.77	500.00	-----
Cavendish.....	2,345.05	20	1,876.00	469.05	-----	-----
Chester.....	4,150.02	25	3,041.68	608.34	500.00	-----
Hartford.....	20,732.69	45	17,765.12	1,967.57	1,000.00	-----
Hartland.....	3,446.82	25	2,039.02	407.80	1,000.00	-----
Ludlow.....	3,981.14	20	2,384.91	596.23	1,000.00	-----
Norwich.....	2,976.82	30	1,908.70	318.12	750.00	-----
Plymouth.....	1,048.63	20	598.90	149.73	-----	300.00
Pomfret.....	1,789.05	25	1,242.57	246.48	300.00	-----
Reading.....	1,613.94	40	1,256.80	157.14	200.00	-----
Rochester.....	4,460.46	35	3,027.90	432.56	1,000.00	-----
Royalton.....	5,273.64	-----	2,741.47	437.37	500.00	1,594.80
Sharon.....	1,692.24	20	953.79	238.45	500.00	-----
Springfield.....	5,118.39	20	1,800.00	2,318.39	1,000.00	-----
Stockbridge.....	2,362.69	-----	1,867.61	195.08	300.00	-----
Weathersfield.....	2,629.56	20	1,303.65	325.91	1,000.00	-----
Weston.....	1,201.47	35	1,040.43	161.04	-----	-----
West Windsor.....	1,393.93	30	990.78	153.15	250.00	-----
Windsor.....	3,128.19	20	1,487.46	640.73	1,000.00	-----
Woodstock.....	8,367.08	20	6,582.27	784.81	1,000.00	-----
Total.....	87,469.53	-----	60,462.22	11,812.51	13,300.00	1,894.80
Grand total for State.....	617,327.79	-----	388,542.63	96,754.36	115,684.38	16,346.42

MASSACHUSETTS.

TABLE 10.—Town revenues applied to roads and bridges outside of incorporated cities 1914.

County and town.	Total town revenues applied to roads and bridges.	Amounts appropriated for—				Amounts paid.	
		Highway repairs.	Highway construction.	Bridge repair.	Bridge construction.	State on State highways covering town's share of cost.	County on county highways.
Barnstable:							
Barnstable.....	\$21,272.93	\$19,300.00		\$800.00	\$800.00	\$372.93	
Bourne.....	41,452.94	10,314.16	\$30,872.82			265.96	
Brewster.....	8,391.00	1,500.00	6,500.00			391.00	
Chatham.....	11,028.04	10,800.00				228.04	
Dennis.....	7,810.43	3,780.00	150.00	200.00	3,356.22	324.21	
Eastham.....	725.00	175.00	500.00	50.00			
Falmouth.....	36,260.40	18,200.00	5,500.00	1,200.00	10,614.56	745.84	
Harwich.....	6,125.00	2,425.00	3,500.00	200.00			
Mashpee.....	390.00	350.00		40.00			
Orleans.....	9,232.54	4,000.00	4,000.00	100.00	1,000.00	132.54	
Provincetown.....	6,933.79	6,880.00				53.79	
Sandwich.....	5,500.25	3,745.38	1,570.43			184.44	
Truro.....	3,929.34	1,800.00	2,000.00			129.34	
Wellfleet.....	1,395.46	1,200.00				195.46	
Yarmouth.....	7,790.24	3,100.00	1,000.00		3,356.23	334.01	
Berkshire:							
Adams.....	23,080.19	16,746.87	4,156.29	2,004.55		172.48	
Alford.....	1,006.31	606.31	200.00			200.00	
Becket.....	5,700.00	2,700.00	1,300.00				
Cheshire.....	3,041.97	3,041.97					
Clarksburg.....	1,254.50	950.00		250.00		54.50	
Dalton.....	4,600.00	3,600.00		1,000.00			
Egremont.....	4,985.20	1,661.98	2,726.72		596.50		
Florida.....	2,500.00	2,500.00					
Great Barrington.....	14,700.00	10,700.00			4,000.00		
Hancock.....	1,600.00	1,200.00	400.00				
Hinsdale.....	2,126.61	1,476.61		650.00			
Lanesborough.....	2,646.63	2,279.62	264.01			103.00	
Lee.....	5,618.00	5,000.00				618.00	
Lenox.....	161,720.21	10,000.00	150,000.00			1,720.21	
Monterey.....	3,116.37	1,000.00	150.00	200.00	750.00	1,016.37	
Mount Washington.....	2,403.87	571.47	1,832.40				
New Ashford.....	400.00	200.00		200.00			
New Marlboro.....	6,800.00	4,300.00	1,250.00		500.00	750.00	
Otis.....	2,731.01	1,700.00				612.50	\$418.51
Peru.....	1,200.00	1,200.00					
Richmond.....	5,400.00	3,000.00	1,200.00			1,200.00	
Sandisfield.....	3,395.90	1,413.29	1,429.77	552.84			
Savoy.....	5,500.00	1,500.00	2,000.00			2,000.00	
Sheffield.....	10,500.00	4,500.00	6,000.00				
Stockbridge.....	8,074.05	6,945.20		809.97		318.88	
Tyringham.....	3,606.52	1,262.66	2,343.86				
Washington.....	2,200.00	1,700.00	500.00				
West Stockbridge.....	6,734.86	4,210.49	1,537.02	987.35			
Williamstown.....	24,281.13	14,500.00	4,000.00	1,600.00	4,000.00	181.13	
Windsor.....	1,500.00	1,500.00					
Bristol:							
Acushnet.....	6,029.16	6,000.00				29.16	
Attleboro.....	38,054.79	37,893.43				161.36	
Berkley.....	4,202.91	1,194.91	2,970.00			38.00	
Dartmouth.....	40,967.32	21,026.67	17,187.22	6.59	2,645.44	101.40	
Dighton.....	5,290.06	4,400.00		696.00		194.06	
Easton.....	10,026.20	10,000.00				26.20	
Fairhaven.....	16,938.00	3,000.00	1,100.00	1,759.00	6,850.00	4,229.00	
Freetown.....	11,064.94	3,836.26	4,000.00			3,228.68	
Mansfield.....	18,231.58	7,000.00	9,100.00		2,100.00	31.58	
North Attleboro.....	20,133.78	18,000.00	2,000.00			133.78	
Norton.....	4,673.99	4,500.00				173.99	
Raynham.....	5,574.10	2,500.00	3,000.00			74.10	
Rehoboth.....	3,914.54	3,000.00	725.00			189.54	
Seekonk.....	9,610.01	2,894.81	6,573.09			142.11	
Somerset.....	7,962.67	4,098.85	1,314.71	86.44		2,462.67	
Swansea.....	15,150.00	6,000.00	5,150.00				4,000.00
Westport.....	24,057.56	1,500.00	19,500.00			70.98	2,986.58

¹ Private subscription.² Received from State.³ \$54.35 received from State for this account.⁴ \$30 received from State for this account.⁵ \$1,000 received from State for this account.⁶ \$2,151.67 received from State for this account.⁷ \$3,000 received from State for this account.⁸ Besides this general appropriation of \$1,500 there was \$300 for tarring road and \$2,700 for the purchase of a portable crusher.

MASSACHUSETTS—Continued.

TABLE 10.—Town revenues applied to roads and bridges outside of incorporated cities, 1914—Continued.

County and town.	Total town revenues applied to roads and bridges.	Amounts appropriated for—				Amounts paid.	
		Highway repairs.	Highway construction.	Bridge repair.	Bridge construction.	State on State highways covering town's share of cost.	County on county highways.
Dukes:							
Chilmark.....	\$811.90	\$811.90					
Edgartown.....	3,559.95	1,800.00	\$1,500.00	\$250.00		\$9.95	
Gay Head.....							
Gosnold.....	200.00	200.00					
Oak Bluffs.....	2,455.45	2,000.00	150.00	300.00		5.45	
Tisbury.....	7,885.66	4,885.66	3,000.00				
West Tisbury....	395.93	395.35				.58	
Essex:							
Amesbury.....	14,000.00	12,000.00		2,000.00			
Andover.....	31,900.24	17,900.00	13,600.00			400.24	
Boxford.....	20,020.00	20,020.00					
Danvers.....	18,100.00	15,100.00	3,000.00				
Essex.....	2,905.65	2,707.32	95.00	75.00		28.33	
Georgetown.....	4,300.00	1,800.00	2,500.00				
Groveland.....	6,549.16	3,029.90	3,000.00			519.26	
Hamilton.....	6,142.45	6,000.00				142.45	
Ipswich.....	11,617.54	11,500.00				117.54	
Lynnfield.....	6,003.52	6,003.52					
Manchester.....	64,000.00	29,000.00	35,000.00				
Marblehead.....	13,000.00	13,000.00					
Merrimac.....	2,083.72	1,925.76				157.96	
Methuen.....	29,152.83	27,435.94	1,315.01			401.88	
Middleton.....	2,033.00	1,875.00		158.00			
Nahant.....	13,534.76	13,034.76	300.00				
Newbury.....	6,435.75	3,200.00			\$1,000.00	235.75	
North Andover..	15,019.90	6,000.00	3,200.00	5,170.30		649.60	
Peabody.....	36,355.39	20,018.78	16,084.63	251.98			
Rockport.....	4,180.00	4,000.00				180.00	
Rowley.....	2,568.65	2,250.00				318.65	
Salisbury.....	6,000.00	4,000.00	1,500.00	500.00			
Saugus.....	12,266.35	12,000.00				266.35	
Swampscott.....	81,023.43	19,953.37	60,434.96	175.00		460.10	
Topsfield.....	11,731.59	10,731.59				1,000.00	
Wenham.....	4,245.46	2,500.00	1,547.46			198.00	
West Newbury....	3,360.55	500.00	2,000.00	500.00		360.55	
Franklin:							
Ashfield.....	3,500.00	2,000.00	1,000.00	500.00			
Barnardston.....	1,627.15	1,519.53				107.62	
Buckland.....	3,014.42	2,500.00		300.00		214.42	
Charlemont.....	2,774.92	2,524.92				250.00	
Colrain.....	4,755.10	2,500.00	1,175.00	1,000.00		80.10	
Conway.....	4,000.00	3,300.00	700.00				
Deerfield.....	8,210.28	2,701.32	1,991.31	92.62	2,570.99	854.04	
Erving.....	1,400.00	1,400.00					
Gill.....	1,350.00	1,000.00	350.00				
Greenfield.....	20,329.60	20,000.00				329.60	
Hawley.....	1,800.00	1,700.00	100.00				
Heath.....	1,300.00	1,300.00					
Leverett.....	1,500.00	1,150.00			350.00		
Leyden.....	1,000.00	1,000.00					
Monroe.....	1,595.90	1,375.05	220.85				
Montague.....	27,066.05	8,851.94	3,072.13	3,710.79	1,834.79	372.36	\$9,224.04
New Salem.....	1,900.00	1,400.00	500.00				
Northfield.....	4,149.48	3,000.00		1,149.48			
Orange.....	6,000.00	6,000.00					
Rowe.....	1,600.00	1,600.00					
Shelburne.....	6,700.00	4,200.00	1,500.00		1,000.00		
Shutesbury.....	1,200.00	1,200.00					
Sunderland.....	6,833.00	600.00		150.00	6,000.00	83.00	
Warwick.....	2,000.00	2,000.00					
Wendell.....	4,000.00	1,200.00	2,800.00				
Whately.....	6,800.00	1,500.00	2,500.00	300.00		2,500.00	
Hampden:							
Agawam.....	12,757.27	5,000.00	7,308.39			448.88	
Blandford.....	17,954.31	3,653.83	13,600.00	700.48			
Brimfield.....	2,618.03	1,525.46	500.00	400.00		192.57	
Chester.....	3,330.99	1,800.00		1,200.00		330.99	
East Longmeadow	3,080.00	1,500.00	1,500.00			80.00	
Granville.....	2,800.00	2,000.00	500.00		300.00		

MASSACHUSETTS—Continued.

TABLE 10.—*Town revenues applied to roads and bridges outside of incorporated cities, 1914—Continued.*

County and town.	Total town revenues applied to roads and bridges.	Amounts appropriated for—				Amounts paid.	
		Highway repairs.	Highway construction.	Bridge repair.	Bridge construction.	State on State highways covering town's share of cost.	County on county highways.
Hampden—Contd.							
Hampden.....	\$1,300.00	\$1,100.00	\$100.00			\$100.00	
Holland.....	453.35	400.00			\$53.35		
Longmeadow.....	5,700.00	3,500.00	2,200.00				
Ludlow.....	16,700.00	9,000.00	7,700.00				
Monson.....	8,499.86	6,240.29	2,259.57				
Montgomery.....	548.19	490.62		\$57.57			
Palmer.....	13,631.13	9,500.00	1,700.00	1,500.00		931.13	
Russell.....	4,333.00	4,000.00				333.00	
Southwick.....	5,750.00	2,000.00	1,800.00	400.00	{ 1,200.00 1,350.00 }		
Tolland.....	1,650.00	1,450.00		200.00			
Wales.....	821.48	800.00				21.48	
Westfield.....	46,215.76	20,400.00	6,000.00	2,000.00	17,000.00	815.76	
West Springfield.....	40,959.04	11,785.09	27,612.06	1,149.09		412.80	
Wilbraham.....	4,351.83	4,000.00				351.83	
Hampshire:							
Amherst.....	27,000.00	9,000.00	6,000.00			12,000.00	
Belchertown.....	3,117.50	2,500.00	500.00			117.50	
Chesterfield.....	2,100.00	2,100.00					
Cummington.....	1,823.75	1,440.00	383.75				
Easthampton.....	24,654.57	9,500.00	14,987.00			167.57	
Enfield.....	1,500.00	1,500.00					
Goshen.....	1,400.00	800.00	300.00			300.00	
Granby.....	4,800.00	1,800.00	1,500.00		500.00	1,000.00	
Greenwich.....	1,200.00	700.00	500.00				
Hadley.....	16,374.41	2,424.95	13,253.79	363.47		332.20	
Hatfield.....	9,850.00	3,000.00	6,600.00			250.00	
Huntington.....	5,757.24	2,474.09	2,147.90	416.21	606.04	113.00	
Middlefield.....	1,357.80	626.90	569.05	161.85			
Pelham.....	3,400.00	1,400.00	1,500.00			500.00	
Plainfield.....	900.00	800.00	100.00				
Prescott.....	1,200.00	1,200.00					
South Hadley.....	7,754.32	6,920.01	40.06			794.25	
Southampton.....	2,500.00	2,000.00	500.00				
Ware.....	13,099.97	12,629.72				470.25	
Westhampton.....	1,200.00	900.00	300.00				
Williamsburg.....	9,559.40	2,774.57	2,380.46	150.43	2,566.23	187.71	
Worthington.....	2,500.00	2,000.00	500.00				
Middlesex:							
Acton.....	5,745.34	3,770.78	412.20	1,081.11		481.25	
Arlington.....	71,170.94	44,710.94	26,460.00				
Ashby.....	3,754.52	2,500.00	1,000.00			254.52	
Ashland.....	6,456.41	2,800.00			3,500.00	156.41	
Ayer.....	5,014.00	2,500.00	2,500.00			14.00	
Bedford.....	15,216.31	{ 1,788.14 4,000.00 }	9,428.17				
Belmont.....	25,000.00	25,000.00					
Billerica.....	17,912.73	9,812.73	5,000.00	600.00		2,500.00	
Boxboro.....	1,365.51	1,000.00	200.00			165.51	
Burlington.....	4,890.00	2,700.00	2,000.00			190.00	
Carlisle.....	1,242.10	1,242.10					
Chelmsford.....	11,684.83	7,160.00				526.59	\$3,998.24
Concord.....	25,000.00	25,000.00					
Dracut.....	18,086.20	3,000.00	15,000.00			86.20	
Dunstable.....	828.00	828.00					
Frammingham.....	56,060.76	30,142.68	25,918.08				
Groton.....	6,000.00	6,000.00					
Holliston.....	5,835.00	2,800.00	500.00			279.70	2,255.30
Hopkinton.....	10,000.00	5,000.00	5,000.00				
Hudson.....	13,725.39	9,200.00				4,525.39	
Lexington.....	30,601.14	30,227.22				373.92	
Lincoln.....	12,000.00	12,000.00					
Maynard.....	10,500.00	4,000.00			6,500.00		
Natick.....	26,972.55	26,226.99		400.00		345.56	
North Reading.....	8,150.00	1,000.00	7,000.00			150.00	
Pepperell.....	5,554.00	2,850.00	1,140.00	1,450.00		114.00	
Reading.....	23,179.65	19,900.65	2,950.00			329.00	
Sherborn.....	6,050.00	5,250.00	800.00				
Shirley.....	2,600.00	1,500.00		200.00	900.00		

¹ Railings.² Received from State \$1,500 and from county \$1,000 on this account.³ Excise.

MASSACHUSETTS—Continued.

TABLE 10.—Town revenues applied to roads and bridges outside of incorporated cities, 1914—Continued.

County and town.	Total town revenues applied to roads and bridges.	Amounts appropriated for—				Amounts paid.	
		Highway repairs.	Highway construction.	Bridge repair.	Bridge construction.	State on State highways covering town's share of cost.	County on county highways.
Middlesex—Contd.							
Stoneham.....	\$17,030.14	\$11,903.82	\$4,876.75			\$249.57	
Stow.....	5,100.00	2,700.00	1,000.00	\$400.00		1,000.00	
Tewksbury.....	8,750.00	750.00	4,000.00				\$4,000.00
Townsend.....	2,687.59	1,800.00	500.00	50.00		337.59	
Tyngsboro.....	538.50	200.00				338.50	
Wakefield.....	44,812.19	14,989.95	29,822.24				
Watertown.....	38,179.88	15,792.00	21,000.00	558.00		154.86	675.02
Wayland.....	14,333.66	3,504.54	10,589.56			239.56	
Weston.....	19,932.16	1,932.16	18,000.00				
Wilmington.....	3,514.92	1,800.00	1,500.00			214.92	
Winchester.....	66,000.00	51,000.00	15,000.00				
Westford.....	5,014.23	4,000.00	800.00			214.23	
Nantucket:							
Nantucket.....	19,720.82	9,000.00	10,000.00			720.82	
Norfolk:							
Avon.....	7,000.00	1,000.00				6,000.00	
Bellingham.....	7,446.65	2,843.43	2,157.09		\$2,359.82	86.31	
Braintree.....	21,918.56	21,918.56					
Brookline.....	134,533.07	78,200.00	54,333.07	2,000.00			
Canton.....	20,386.07	16,277.47	3,249.21		770.00	89.39	
Cohasset.....	27,020.00	20,000.00	6,900.00	120.00			
Dedham.....	52,504.81	28,626.22	9,273.11		14,602.61	2.87	
Dover.....	8,201.11	7,409.34	506.10	203.12		82.55	
Foxboro.....	4,845.79	4,255.79			590.00		
Franklin.....	9,589.84	9,238.35				351.49	
Holbrook.....	2,200.00	1,800.00				400.00	
Medfield.....	6,700.00	6,000.00		200.00	500.00		
Medway.....	4,554.65	3,316.98	994.42	143.25			
Millis.....	2,700.00	2,700.00					
Milton.....	77,720.65	27,301.47	30,000.00			20,419.18	
Needham.....	22,219.13	13,108.51	9,029.02			81.60	
Norfolk.....	2,093.88	2,000.00				93.88	
Norwood.....	33,511.16	12,076.98	21,095.87	265.00		73.31	
Plainville.....	1,628.68	1,400.00		150.00		78.68	
Randolph.....	7,497.00	7,497.00					
Sharon.....	8,650.00	6,200.00	2,450.00				
Walpole.....	10,589.26	7,875.00	863.00	1,750.00		101.26	
Wellesley.....	28,841.21	20,124.00	8,600.00			117.21	
Weymouth.....	28,818.00	22,625.00	5,993.00	200.00			
Westwood.....	7,550.00	7,550.00					
Wrentham.....	5,000.00	2,500.00	2,500.00				
Plymouth:							
Abington.....	5,173.96	4,150.00	100.00	800.00		123.96	
Bridgewater.....	9,353.92	5,000.00	4,300.00			53.92	
Carver.....	8,250.00	3,250.00	4,900.00	100.00			
Duxbury.....	24,002.17	7,468.13	12,251.65	15.25	3,235.72	198.27	833.15
East Bridgewater.....	8,648.38	6,452.55	2,059.43	136.40			
Halifax.....	2,800.00	1,800.00	1,000.00				
Hanover.....	3,250.00	2,900.00	300.00	50.00			
Hanson.....	13,350.00	6,575.00	6,575.00	100.00	100.00		
Hingham.....	27,983.27	21,096.48	3,812.62	220.00	2,689.45	164.72	
Hull.....	36,381.09	13,899.49	22,481.60				
Kingston.....	6,030.83	3,866.80	1,997.63			62.26	104.14
Lakeville.....	5,796.25	5,629.32				166.93	
Marion.....	19,261.72	5,500.00	7,114.00			6,647.72	
Marshfield.....	12,746.70	10,003.00	1,800.00			946.70	
Mattapoisett.....	6,593.63	6,500.00				93.63	
Middleboro.....	26,584.56	12,500.00	4,800.00		1,500.00	420.21	7,364.35
Norwell.....	4,990.00	1,000.00	3,990.00				
Pembroke.....	5,757.29	3,500.00	2,000.00	250.00		7.29	
Plymouth.....	41,023.30	25,228.52	15,415.90			378.88	
Plympton.....	2,385.21	1,065.61	1,228.99	90.61			
Rochester.....	2,510.65	2,450.00				60.65	
Rockland.....	19,012.66	18,908.12				104.54	
Scituate.....	28,311.24	5,000.00	23,000.00			311.24	
Wareham.....	36,014.77	16,914.11	3,453.79		15,294.20	352.67	
Whitman.....	18,018.00	9,518.00	5,500.00			3,090.00	
West Bridgewater.....	5,012.78	2,000.00	2,478.41	457.72		76.65	

¹ \$500 received from State for this expense.² \$1,582.50 received from State for this expense.³ \$700 received from State for this expense.

MASSACHUSETTS—Continued.

TABLE 10.—Town revenues applied to roads and bridges outside of incorporated cities, 1914—Continued.

County and town.	Total town revenues applied to roads and bridges.	Amounts appropriated for—				Amounts paid.	
		Highway repairs.	Highway construction.	Bridge repair.	Bridge construction.	State on State highways covering town's share of cost	County on county highways.
Suffolk:							
Revere.....	\$41,800.00	\$25,000.00	\$16,400.00	\$400.00			
Winthrop.....	31,510.00	17,500.00	14,010.00				
Worcester:							
Ashburnham.....	3,035.85	2,700.00		300.00		\$35.85	
Athol.....	11,645.37	11,645.37					
Auburn.....	2,057.26	1 2,057.26				374.02	
Barre.....	3,374.02	3,000.00					
Barre.....	7,475.50	5,300.00	2,000.00			175.50	
Berlin.....	1,400.00	1 1,400.00				400.00	
Blackstone.....	5,350.00	3,000.00	1,500.00	850.00			
Bolton.....	2,000.00	1,000.00	1,000.00				
Boylston.....	2,593.79	1,920.57	2 597.71	75.51			
Brookfield.....	2,517.87	1,903.28		286.63		327.96	
Charlton.....	6,961.74	1 1,451.11		700.00	\$1,200.00	535.63	
Clinton.....	25,552.73	3,075.00					
Dana.....	700.00	15,932.32	9,156.74	463.67			
Douglas.....	2,504.54	700.00					
Dudley.....	5,000.00	2,353.66				150.88	
Gardner.....	27,218.76	2,500.00	2,500.00				
Grafton.....	18,739.44	27,000.00				218.76	
Hardwick.....	15,500.00	7,877.84	8,000.00			2,661.60	
Harvard.....	4,974.82	4,500.00	10,000.00		1,000.00		
Holden.....	3,000.00	4,850.00				124.82	
Hopedale.....	25,500.00	3,000.00					
Hubbardston.....	5,767.99	25,500.00					
Lancaster.....	9,000.00	3,138.03	3 2,521.21	108.75			
Leicester.....	8,000.00	9,000.00					
Leominster.....	51,491.05	3,000.00	5,000.00				
Lunenburg.....	3,784.36	42,219.64	8,939.54			331.87	
Mendon.....	1,017.80	200.00	3,257.94			326.42	
Milford.....	16,277.02	1 1,017.80					
Millbury.....	7,716.07	2,000.00					
New Braintree.....	2,400.00	13,000.00	3,000.00			277.02	
North Brookfield.....	3,000.00	4,000.00	3,000.00	400.00		316.07	
Northboro.....	4,570.32	1,400.00	500.00			500.00	
Northbridge.....	18,285.29	3,000.00					
Oakham.....	1,400.00	3,855.11	400.00			315.21	
Oxford.....	4,775.42	9,942.09	7,810.46	532.74			
Paxton.....	1,280.00	1,400.00					
Petersham.....	3,800.00	4,426.42				349.00	
Phillipston.....	1,500.00	600.00	500.00			180.00	
Princeton.....	9,222.70	2,800.00	1,000.00				
Royalston.....	2,800.00	5,000.00	2,000.00			2,222.70	
Rutland.....	9,541.49	2,000.00	600.00	200.00			
Shrewsbury.....	5,938.06	2,448.61	4 6,518.98		515.90	58.00	
Southboro.....	8,790.42	3,405.87	1,635.44	350.00		546.75	
Southbridge.....	26,550.00	6,200.00	2,236.16			354.26	
Spencer.....	7,900.00	13,500.00	11,050.00	2,000.00			
Sterling.....	38,032.97	5,000.00	2,500.00	400.00			
Sturbridge.....	8,083.94	3,089.13	5 34,582.59			361.25	
Sutton.....	17,500.00	2 5,000.00	500.00			167.16	\$1,007.00
Templeton.....	4,153.05	3,909.78	5,000.00		500.00	5,000.00	1,000.00
Upton.....	2,500.00	2,500.00	1,000.00	250.00		403.05	
Uxbridge.....	5,672.00	2,500.00					
Warren.....	7,000.00	4,000.00		1,500.00		172.00	
Webster.....	14,948.07	3,000.00	3,000.00	500.00	500.00		
Westboro.....	5,268.35	9,800.00	4,700.00	200.00		248.07	
West Boylston.....	2,596.07	5,268.35					
West Brookfield.....	4,858.50	2,500.00				96.07	
Westminster.....	3,000.00	1,700.00	2,200.00		825.00	133.50	
Winchendon.....	18,700.00	3,000.00	4,000.00	1,000.00	1,000.00		
Total.....	3,839,094.23	2,182,104.25	1,295,198.40	61,182.77	135,983.05	126,759.43	37,866.33

¹ Excise.² \$600 received from State for this expense.³ \$1,500 received from State for this expense.⁴ \$2,470.57 received from State for this expense.⁵ \$32,808.11 received from State for this expense.⁶ State and county tax.

MASSACHUSETTS—Continued.

TABLE 11.—*Expenditures for highway purposes by cities—not including sidewalks and street lighting.*

City.	Total.	City.	Total.	City.	Total.
Attleboro.....	\$25,500.00	Lawrence.....	\$239,375.11	Quincy.....	\$72,002.37
Beverly.....	71,629.35	Lowell.....	199,080.42	Revere.....	21,721.72
Boston.....	3,204,226.11	Lynn.....	125,908.90	Salem.....	62,003.74
Brockton.....	93,084.89	Malden.....	116,137.00	Somerville.....	62,336.61
Cambridge.....	202,450.00	Marlborough.....	52,677.01	Springfield.....	410,574.30
Chelsea.....	59,169.93	Medford.....	53,492.44	Taunton.....	83,967.15
Chicopee.....	45,149.08	Melrose.....	40,187.76	Waltham.....	40,258.99
Everett.....	29,513.31	New Bedford.....	203,105.62	Woburn.....	37,292.14
Fall River.....	107,102.29	Newburyport.....	18,295.75	Worcester.....	161,888.59
Fitchburg.....	203,967.96	Newton.....	90,100.00		
Gloucester.....	47,234.58	North Adams.....	27,890.26	Total.....	6,693,206.83
Haverhill.....	89,348.91	Northampton.....	22,118.95		
Holyoke.....	163,232.30	Pittsfield.....	211,183.29		

RHODE ISLAND.

TABLE 12.—*Revenues appropriated by towns from general funds for town roads and bridges, 1914.*

County and town.	Amount.	County and town.	Amount.	County and town.	Amount.
Bristol:		Newport—Cont'd.		Providence—Cont'd.	
Barrington.....	\$7,000	New Shoreham...	\$1,500	Scituate.....	\$4,000
Bristol.....	7,000	Portsmouth.....	8,500	Smithfield.....	4,000
Warren.....	6,300	Tiverton.....	4,500	Washington:	
Kent:		Providence:		Charleston.....	1,800
Coventry.....	7,500	Burrillville.....	9,000	Exeter.....	1,500
East Greenwich.....	3,000	Cumberland.....	156,000	Hopkinton.....	2,500
Warwick.....	2,500	East Providence..	2,200	Narragansett.....	18,000
West Greenwich.....	3,000	Foster.....	2,200	North Kingston...	6,000
West Warwick.....	12,000	Gloucester.....	2,000	Richmond.....	3,000
Newport:		Johnston.....	5,000	South Kingston...	9,000
Jamestown.....	8,000	Lincoln.....	3,000	Westerly.....	27,500
Little Compton.....	1,500	North Providence.	5,000		
Middletown.....	7,000	North Smithfield..	8,000	Total.....	244,000

¹ Includes \$40,000 for bridges.

CONNECTICUT.

TABLE 13.—*Town revenue applied to roads and bridges, fiscal year 1914-15.*

County and town.	Total.	Appropriated by towns for—	
		Town roads.	Town bridges.
Fairfield:			
Bethel.....	\$4,439.15	\$4,439.15	.....
Brookfield.....	3,417.51	3,111.30	\$306.21
Danbury.....	25,154.07	21,787.11	3,366.96
Darien.....	11,415.43	11,415.43	.....
Easton.....	3,099.13	2,863.95	235.18
Fairfield.....	17,103.02	13,857.90	3,245.12
Greenwich.....	113,508.33	113,508.33	.....
Huntington.....	8,887.24	8,887.24	.....
Monroe.....	2,147.19	2,092.85	54.34
New Canaan.....	16,102.79	13,405.87	2,696.92
New Fairfield.....	1,875.92	1,548.00	327.92
Newtown.....	13,198.94	9,517.64	3,681.30
Redding.....	5,488.82	4,274.49	1,214.33
Ridgefield.....	11,820.34	10,720.49	1,099.85
Sherman.....	2,028.15	1,690.14	338.01
Stamford.....	28,606.88	26,083.78	2,523.10
Stratford.....	13,778.68	13,009.83	768.85
Trumbull.....	1,819.24	1,665.04	154.20
Weston.....	1,679.86	1,679.86	.....
Westport.....	29,809.62	19,742.48	10,067.14
Wilton.....	5,151.55	2,893.24	2,258.31

CONNECTICUT—Continued.

TABLE 13.—Town revenue applied to roads and bridges, fiscal year 1914-15—Continued.

County and town.	Total.	Appropriated by towns for—	
		Town roads.	Town bridges.
Hartford:			
Avon.....	\$1,620.20	\$1,620.20	.....
Berlin.....	5,863.19	5,863.19	.....
Bloomfield.....	10,408.13	9,382.07	\$1,026.06
Canton.....	8,752.80	6,142.26	2,610.54
Hartford.....	3,010.37	2,987.87	22.50
East Hartford.....	22,678.53	22,085.73	592.80
East Windsor.....	9,839.97	7,614.77	2,225.20
Enfield.....	28,245.16	28,245.16	.....
Farmington.....	8,121.35	8,121.35	.....
Glastonbury.....	17,246.56	15,842.36	1,404.20
Granby.....	3,232.76	2,445.26	787.50
Hartland.....	1,579.12	1,579.12	.....
Manchester.....	32,603.85	26,788.96	5,814.89
Marlboro.....	1,103.94	1,001.96	101.98
Newington.....	2,151.52	2,151.52	.....
Plainville.....	5,039.87	5,039.87	.....
Rocky Hill.....	1,433.98	1,014.55	419.43
Simsbury.....	15,990.43	12,798.91	3,191.52
Southington.....	9,694.15	9,694.15	.....
South Windsor.....	15,299.26	14,847.15	452.11
Suffield.....	14,801.46	14,226.41	575.05
West Hartford.....	24,266.20	21,612.62	2,653.58
Wethersfield.....	3,763.01	3,763.01	.....
Windsor.....	13,148.40	12,389.42	758.98
Windsor Locks.....	4,302.67	4,302.67	.....
Litchfield:			
Bethlehem.....	1,750.36	1,168.99	581.37
Bridgewater.....	1,781.14	1,565.24	215.90
Canaan.....	1,879.16	1,879.16	.....
Colebrook.....	6,709.10	2,307.73	4,401.37
Cornwall.....	6,009.89	5,044.84	965.05
Goshen.....	4,317.71	4,317.71	.....
Harwinton.....	2,973.54	1,966.22	1,007.32
Kent.....	5,850.95	5,850.95	.....
Litchfield.....	12,123.67	10,178.54	1,945.13
Morris.....	1,182.61	931.05	251.56
New Hartford.....	7,524.66	4,927.11	2,597.55
New Milford.....	18,374.45	15,015.29	3,359.16
Norfolk.....	10,337.36	10,337.36	.....
North Canaan.....	5,432.78	5,432.78	.....
Plymouth.....	3,394.98	2,682.47	712.51
Roxbury.....	2,345.50	2,083.94	261.56
Salisbury.....	6,376.09	6,376.09	.....
Sharon.....	10,020.82	10,020.82	.....
Thomaston.....	5,914.18	5,152.34	761.84
Torrington.....	20,173.47	20,173.47	.....
Warren.....	1,552.32	1,369.20	183.12
Washington.....	6,757.69	5,909.85	847.84
Watertown.....	10,563.34	8,649.25	1,914.09
Winchester.....	32,233.58	20,316.50	11,917.08
Woodbury.....	4,817.99	4,817.99	.....
Middlesex:			
Chatham.....	6,067.31	6,067.31	.....
Chester.....	4,295.36	4,295.36	.....
Clinton.....	2,597.29	2,597.29	.....
Cromwell.....	1,468.98	1,189.65	279.33
Durham.....	2,409.03	1,336.31	1,072.72
East Haddam.....	5,136.21	5,136.21	.....
Essex.....	1,735.71	1,735.71	.....
Haddam.....	3,409.49	3,409.49	.....
Killingworth.....	2,216.92	1,979.61	237.31
Middlefield.....	3,596.00	2,000.70	1,595.30
Middletown.....	16,604.22	13,588.72	3,015.50
Old Saybrook.....	1,268.78	749.62	519.16
Portland.....	2,858.02	2,504.62	353.40
Saybrook.....	2,132.34	2,132.34	.....
Westbrook.....	1,888.65	1,812.35	76.30
New Haven:			
Beacon Falls.....	1,019.87	634.33	385.54
Bethany.....	2,978.23	2,978.23	.....
Branchford.....	6,084.72	6,084.72	.....
Cheshire.....	3,173.77	3,173.77	.....
East Haven.....	1,558.39	1,514.50	43.89
Guilford.....	4,557.03	4,058.95	498.08

CONNECTICUT—Continued.

TABLE 13.—Town revenue applied to roads and bridges, fiscal year 1914-15—Continued.

County and town.	Total.	Appropriated by towns for—	
		Town roads.	Town bridges.
New Haven—Continued			
Madison.....	\$4,580.06	\$3,944.77	\$635.29
Meriden.....	24,902.38	24,902.38	.....
Middlebury.....	2,443.57	2,030.21	413.36
Milford.....	14,043.42	13,390.48	652.94
North Branford.....	1,894.68	1,471.56	423.12
North Haven.....	4,037.79	3,748.03	289.76
Orange.....	16,525.79	13,057.05	3,468.74
Oxford.....	2,665.53	2,665.53	.....
Prospect.....	1,181.60	1,181.60	.....
Seymour.....	9,515.84	6,900.88	2,614.96
Southbury.....	4,873.74	4,873.74	.....
Wallingford.....	6,121.07	4,294.34	1,826.73
Wolcott.....	1,911.26	1,911.26	.....
Woodbridge.....	3,613.58	3,347.01	266.57
New London:			
Bozrah.....	1,501.34	951.66	549.68
Colchester.....	3,608.29	3,608.29	.....
East Lyme.....	8,841.17	8,841.17	.....
Franklin.....	1,479.81	1,479.81	.....
Griswold.....	3,893.30	3,321.77	571.53
Groton.....	10,861.65	10,861.65	.....
Lebanon.....	4,071.76	4,071.76	.....
Ledyard.....	3,319.44	3,319.44	.....
Lisbon.....	477.14	428.22	48.92
Lyme.....	1,250.02	1,033.06	216.96
Montville.....	5,185.23	3,855.07	1,330.16
North Stonington.....	3,463.28	3,463.28	.....
Norwich.....	43,901.17	41,537.40	2,363.77
Old Lyme.....	1,374.35	1,374.35	.....
Preston.....	3,483.69	3,483.69	.....
Sprague.....	16,199.90	2,938.24	13,261.66
Stonington.....	18,200.12	16,963.76	1,236.36
Voluntun.....	896.77	896.77	.....
Waterford.....	8,489.28	8,489.28	.....
Tolland:			
Andover.....	752.40	641.32	111.08
Bolton.....	1,247.10	1,247.10	.....
Columbia.....	970.75	888.81	81.94
Coventry.....	4,289.63	2,951.36	1,338.27
Ellington.....	4,911.01	4,911.01	.....
Hebron.....	1,182.76	1,182.76	.....
Mansfield.....	9,139.22	7,907.20	1,232.02
Somers.....	4,174.88	4,174.88	.....
Stafford.....	3,937.03	3,092.11	844.92
Tolland.....	3,704.06	3,704.06	.....
Union.....	995.15	995.15	.....
Vernon.....	10,129.35	9,614.95	514.40
Willington.....	6,248.83	2,443.82	3,805.01
Windham:			
Brooklyn.....	2,161.81	2,161.81	.....
Canterbury.....	2,310.88	911.50	1,399.38
Chaplin.....	879.73	821.03	58.70
Eastford.....	166.71	.....	166.71
Hampton.....	1,404.59	1,270.63	133.96
Killingly.....	4,991.65	3,768.41	1,223.24
Plainfield.....	6,032.39	5,120.37	912.02
Pomfret.....	11,479.52	9,941.19	1,538.33
Putnam.....	4,607.90	1,203.20	3,404.70
Scotland.....	1,279.40	1,279.40	.....
Sterling.....	3,053.21	1,770.06	1,283.15
Thompson.....	7,954.86	7,582.08	372.78
Windham.....	15,860.42	7,970.80	7,889.62
Woodstock.....	7,924.92	6,109.19	1,815.73
Total.....	1,212,780.58	1,059,511.05	153,269.53

APPENDIX B.

TABLES OF BOND ISSUES.

Massachusetts is the only State of the New England group in which the towns have issued road-improvement bonds. The State issues, together with those of the towns, are hereby presented in tabulated form.

MASSACHUSETTS.

TABLE 14.—*Massachusetts State highway bonds.*

Date issued.	Amount issued.	Date of maturity.	Interest rate.	Date issued.	Amount issued.	Date of maturity.	Interest rate.
			<i>Per ct.</i>				<i>Per ct.</i>
1894....	\$300,000	Apr. 1, 1920.....	3.5	1910....	\$52,500	Oct. 1, 1915, to Oct. 1, 1919; \$10,500 each year.	3.5
1895....	400,000	do.....	3.5				
1896....	600,000	do.....	3.5				
1897....	700,000	Apr. 1, 1927.....	3.5	1910....	180,000	Oct. 1, 1920, to Oct. 1, 1939; \$9,000 each year.	3.5
1898....	300,000	Apr. 1, 1928.....	3.5				
1899....	400,000	Apr. 1, 1929.....	3				
1900....	400,000	Apr. 1, 1930.....	3	1911....	66,000	Oct. 1, 1915, to Oct. 1, 1920; \$11,000 each year.	3.5
1901....	350,000	Apr. 1, 1931.....	3				
1902....	10,000	Apr. 1, 1932.....	3				
1902....	365,000	do.....	3.5	1911....	200,000	Oct. 1, 1921, to Oct. 1, 1940; \$10,000 each year.	3.5
1903....	400,000	Apr. 1, 1933.....	3.5				
1904....	300,000	Apr. 1, 1932.....	3.5				
1905....	160,000	Apr. 1, 1915, to Apr. 1, 1930; \$10,000 each year.	3.5	1912....	122,500	Oct. 1, 1915, to Oct. 1, 1921; \$17,500 each year.	3.5
1906....	220,000	Apr. 1, 1915, to Apr. 1, 1936; \$10,000 each year.	3.5	1912....	85,000	Oct. 1, 1922, to Oct. 1, 1926; \$17,000 each year.	3.5
1907....	276,000	Apr. 1, 1915, to Apr. 1, 1937; \$12,000 each year.	3.5	1912....	120,000	Oct. 1, 1927, to Oct. 1, 1936; \$12,000 each year.	3.5
1908....	396,000	Apr. 1, 1915, to Apr. 1, 1938; \$16,500 each year.	3.5	1912....	55,000	Oct. 1, 1937, to Oct. 1, 1941; \$11,000 each year.	3.5
1909....	1,000	Oct. 1, 1914.....	3	1913....	648,000	Oct. 1, 1915, to Oct. 1, 1922; \$81,000 each year.	3.5
1909....	40,000	Oct. 1, 1915, to Oct. 1, 1919; \$8,000 each year.	3				
1909....	120,000	Oct. 1, 1920, to Oct. 1, 1939; \$6,000 each year.	3	1913....	300,000	Oct. 1, 1923, to Oct. 1, 1927; \$60,000 each year.	3.5
1909....	40,000	Oct. 1, 1915, to Oct. 1, 1919; \$8,000 each year.	3.5	1914....	697,500	Oct. 1, 1915, to Oct. 1, 1923; \$77,500 each year.	3.5
1909....	100,000	Oct. 1, 1920, to Oct. 1, 1939; \$5,000 each year.	3.5	1914....	295,000	Oct. 1, 1924, to Oct. 1, 1928; \$59,000 each year.	3.5
				Total	8,699,500		

TABLE 15.—*Town road and bridge bonds and notes.*

County and town.	Total outstanding bonds to Jan. 1, 1915.	Amount expended during 1914.	Amount retired during 1914.	Amount sold during 1914.		
				Amount.	Term in years.	Interest rate.
Barnstable:						<i>Per cent.</i>
Barnstable.....	\$41,500.00					
Bourne.....	40,300.00	\$16,491.33	\$7,100.00			
Brewster.....	13,800.00	3,460.00	2,400.00	\$4,000.00	4	4
Dennis.....	7,652.34	3,356.02	3,750.00	3,356.02	1 to 5	4
Eastham.....	2,020.00		580.00			
Falmouth.....	23,500.00	9,455.15	5,500.00	3,500.00	Demand.	5
Harwich.....	12,590.00	4,101.71	1,709.50	8,100.00	1 to 5	4½ to 5½
Mashpee.....	2,400.00	300.00				
Orleans.....		20,000.00			½ to ½	3.6
Sandwich.....	8,000.00		1,000.00			
Truro.....	2,000.00	2,000.00		2,000.00	5	4
Yarmouth.....	10,356.23	4,356.23	3,250.00	4,356.23	1 to 3	4
Total.....	164,118.57	63,520.44	25,289.50	25,312.25		

MASSACHUSETTS—Continued.

TABLE 15.—Town road and bridge bonds and notes—Continued.

County and town.	Total outstanding bonds to Jan. 1, 1915.	Amount expended during 1914.	Amount retired during 1914.	Amount sold during 1914.		
				Amount.	Term in years.	Interest rate.
Berkshire:						<i>Per cent.</i>
Adams.....	\$41,000.00	-----	\$6,900.00	-----	-----	-----
Lee.....	2,500.00	-----	2,500.00	-----	-----	-----
Monterey.....	700.00	\$700.00	-----	\$700.00	$\frac{1}{2}$	6
Richmond.....	1,000.00	5,000.00	4,000.00	-----	-----	5
Sandisfield.....	1,000.00	-----	-----	-----	-----	-----
Savoy.....	3,000.00	1,500.00	-----	3,000.00	5 to 10	4½ and 5
Stockbridge.....	5,000.00	-----	5,000.00	-----	-----	-----
Windsor.....	-----	-----	-----	1,000.00	6	-----
Total.....	54,200.00	7,200.00	18,400.00	4,700.00	-----	-----
Bristol:						
Dartmouth.....	13,600.00	4,600.00	3,500.00	4,600.00	1 to 4	4 and 6
Dighton.....	15,500.00	8,000.00	2,000.00	8,000.00	4	4 and 5
Fairhaven.....	59,450.00	6,850.00	4,664.00	6,850.00	1 to 5	4½
North Attleboro.....	12,000.00	-----	4,000.00	-----	-----	-----
Norton.....	6,100.00	-----	1,900.00	-----	-----	-----
Somerset.....	7,500.00	2,462.67	1,000.00	3,500.00	1 to 5	4
Swansea.....	2,000.00	-----	-----	-----	-----	-----
Westport.....	27,800.00	14,000.00	7,000.00	16,500.00	1 to 5	4½
Total.....	143,950.00	35,912.67	24,064.00	39,450.00	-----	-----
Dukes:						
Chilmark.....	1,000.00	-----	675.00	-----	-----	-----
Edgartown.....	1,500.00	1,500.00	-----	1,500.00	10	4½
Total.....	2,500.00	1,500.00	675.00	1,500.00	-----	-----
Essex:						
Amesbury.....	13,000.00	-----	3,000.00	-----	-----	-----
Groveland.....	-----	-----	1,000.00	-----	-----	-----
Ipswich.....	5,000.00	-----	-----	-----	-----	-----
Manchester.....	30,000.00	26,402.27	-----	60,000.00	1 to 3	4
Marblehead.....	30,000.00	-----	55,000.00	-----	-----	-----
Nahant.....	25,000.00	-----	5,000.00	-----	-----	-----
Salisbury.....	8,000.00	-----	-----	-----	-----	-----
Swampscott.....	83,840.00	59,621.96	-----	77,600.00	1 to 20	4
Total.....	194,840.00	86,024.23	64,000.00	137,600.00	-----	-----
Franklin:						
Buckland.....	-----	2,200.00	-----	-----	-----	-----
Charlemont.....	-----	-----	1,500.00	-----	-----	-----
Deerfield.....	8,000.00	2,570.99	1,000.00	-----	-----	-----
Monroe.....	250.00	-----	250.00	-----	-----	-----
Montague.....	8,000.00	1,000.00	1,000.00	-----	-----	-----
Northfield.....	-----	-----	-----	30,000.00	30	3½
Sunderland.....	5,500.00	6,250.00	250.00	6,000.00	1 to 5	5
Total.....	21,750.00	12,020.99	4,000.00	36,000.00	-----	-----
Hampden:						
East Longmeadow.....	1,250.00	1,250.00	1,000.00	1,250.00	1	5
Longmeadow.....	32,500.00	-----	6,000.00	-----	-----	-----
Palmer.....	-----	-----	5,900.00	-----	-----	-----
Russell.....	10,000.00	-----	1,600.00	-----	-----	-----
West Springfield.....	17,000.00	-----	1,000.00	-----	-----	-----
Total.....	60,750.00	1,250.00	15,500.00	1,250.00	-----	-----
Hampshire:						
Belchertown.....	-----	3,559.29	-----	-----	-----	-----
Blandford.....	5,600.00	2,600.00	1,000.00	2,600.00	5	4½
Granby.....	-----	2,500.00	3,500.00	-----	-----	-----
Hatfield.....	6,000.00	6,600.00	-----	6,600.00	1 to 3	4½
Huntington.....	4,500.00	-----	500.00	-----	-----	-----
South Hadley.....	12,735.86	-----	4,250.00	-----	-----	-----
Ware.....	31,100.00	-----	4,850.00	-----	-----	-----
Williamsburg.....	2,500.00	2,500.00	-----	2,500.00	1 to 10	5
Total.....	62,435.86	17,759.29	14,100.00	11,700.00	-----	-----

MASSACHUSETTS—Continued.

TABLE 15.—Town road and bridge bonds and notes—Continued.

County and town.	Total outstanding bonds to Jan. 1, 1915.	Amount expended during 1914.	Amount retired during 1914.	Amount sold during 1914.		
				Amount.	Term in years.	Interest rate.
Middlesex:						<i>Per cent.</i>
Arlington.....	\$18,700.00	\$9,227.79	\$6,000.00	\$8,700.00	1 to 10	4 and 4½
Ashland.....	2,500.00	.....	.....	2,500.00	1 to 5	.....
Ayer.....	4,000.00	.....	500.00	5,000.00	1 to 10	4
Bedford.....	3,000.00	2,000.00	1,000.00	2,000.00	1 and 2	5½
Billerica.....	13,000.00	.....	2,000.00	13,000.00	1 to 6	4½
Concord.....	50,500.00	15,836.58	21,000.00	5,000.00	1 to 5	4
Dracut.....	11,000.00	.....	2,000.00	.....	.....	.....
Holliston.....	4,000.00	.....	1,000.00	5,000.00	1 to 5	.....
Hopkinton.....	.....	5,000.00	.....	.....	.....	.....
Tewksbury.....	2,000.00	2,000.00	.....	2,000.00	.....	4½
Tyngsboro.....	350.00	127.50	127.50	.....	.....	.....
Wakefield.....	30,000.00	23,700.00	6,000.00	18,000.00	1 to 3	4
Watertown.....	111,000.00	6,516.11	11,000.00	8,000.00	3 and 5	4½
Wayland.....	8,000.00	6,000.00	500.00	6,000.00	1 to 3	4½ and 5
Total.....	258,050.00	70,407.98	51,127.50	85,200.00	.....	.....
Nantucket: Nantucket.....	43,500.00	.....	6,500.00	.....	.....	.....
Norfolk:						
Bellingham.....	1,600.00	1,600.00	1,000.00	1,600.00	1	4
Brookline.....	276,750.00	18,454.21	57,050.00	40,000.00	1 to 8	4
Dedham.....	32,740.00	21,425.61	5,500.00	25,000.00	1 to 20	4
Medfield.....	1,000.00	.....	2,500.00	.....	.....	.....
Medway.....	1,458.69	.....	.....	.....	.....	.....
Millis.....	2,200.00	.....	1,600.00	.....	.....	.....
Norwood.....	5,200.00	2,900.00	1,000.00	2,900.00	1 and 2	4
Walpole.....	1,500.00	.....	1,500.00	.....	.....	.....
Weymouth.....	3,000.00	.....	1,000.00	.....	.....	.....
Total.....	323,948.69	44,379.82	71,150.00	69,500.00	.....	.....
Plymouth:						
Duxbury.....	22,000.00	15,487.37	.....	22,000.00	1 to 5	4½
East Bridgewater.....	1,500.00	.....	1,500.00	.....	.....	.....
Hingham.....	13,372.20	.....	5,500.00	.....	.....	.....
Hull.....	89,675.00	19,954.78	.....	17,000.00	1 to 10	4
Lakeville.....	1,500.00	.....	1,500.00	.....	.....	.....
Marion.....	2,200.00	2,200.00	.....	2,200.00	1	6
Middleboro.....	3,200.00	4,800.00	.....	3,200.00	1 and 2	4½
Plymouth.....	13,500.00	.....	.....	.....	.....	.....
Wareham.....	13,920.00	13,500.00	1,710.00	13,500.00	.....	.....
Whitman.....	3,000.00	1,308.55	1,000.00	.....	.....	.....
Total.....	163,867.20	57,250.70	11,210.00	57,900.00	.....	.....
Worcester:						
Ashburnham.....	1,500.00	.....	1,500.00	.....	.....	.....
Athol.....	46,500.00	8,715.77	7,750.00	.....	.....	.....
Blackstone.....	7,000.00	5,350.00	1,500.00	4,500.00	1 to 8	3 and 4½
Brookfield.....	4,967.50	.....	.....	.....	.....	.....
Clinton.....	9,400.00	.....	2,400.00	.....	.....	.....
Grafton.....	11,470.00	2,485.46	1,100.00	3,000.00	6	4
Hardwick.....	14,500.00	14,500.00	.....	14,500.00	.....	4
Northbridge.....	2,500.00	.....	1,000.00	.....	.....	.....
Princeton.....	1,950.00	.....	.....	1,950.00	1 to 2	4 and 5
Rutland.....	500.00	500.00	.....	500.00	1 to 5	5
Southbridge.....	.....	11,050.00	3,683.33	11,050.00	3	4
Spencer.....	.....	.....	1,050.00	.....	.....	.....
Sterling.....	4,000.00	.....	1,000.00	.....	.....	.....
Templeton.....	2,000.00	.....	2,000.00	.....	.....	.....
Uxbridge.....	5,000.00	.....	.....	5,000.00	5	4½
West Brookfield.....	825.00	812.15	.....	825.00	1 and 2	6
Total.....	112,112.50	43,413.38	22,983.33	41,325.00	.....	.....
Grand total.....	1,606,022.82	440,639.50	328,999.33	511,437.25	.....	.....

APPENDIX C.

ROAD MILEAGE TABLES.

Tables referred to in the text, showing the miles of public roads in the respective States, outside of the incorporated cities.

MAINE.

TABLE 16.—*Miles of public roads outside of incorporated cities, 1914.*

County and town.	Total mileage, all roads.	Surfaced roads.						Graded and drained earth roads.	
		Macadam.		Gravel.	Other hard surfaced roads. ¹	Total surfaced.	Per-centage of total surfaced.		Increase in surfaced mileage over 1909.
		Plain.	Bitumi-nous.						
Androscoggin:									
Durham.....	80.00			1.47		1.47		0.26	
East Livermore.....	33.00	0.73	0.46	0.56		1.75			
Greene.....	80.00			3.86		3.86		.78	
Leeds.....	80.00			3.20		3.20			
Lisbon.....	65.00		.12	2.39	10.00	12.51			
Livermore.....	90.00	.06		1.48		1.54			
Mechanic Falls.....	28.00			2.20		2.20			
Minot.....	125.00			.85		.85		.11	
Poland.....	80.00			6.27		6.27		.22	
Turner.....	224.40			3.23	10.00	13.23			
Wales.....	28.00			1.49		1.49		.26	
Webster.....	45.00			2.79		2.79			
Total.....	958.40	.79	.58	29.79	20.00	51.16	5.33	-157.52	
Aroostook:									
Allagash.....	14.00								
Amity.....	19.00			3.92		3.92			
Ashland.....	33.00			9.60		9.60		1.76	
Bancroft.....	25.00			.77		.77		.65	
Benedicta.....	12.00			1.26		1.26		.06	
Blaine.....	30.00			1.18		1.18			
Bridgewater.....	26.00			11.94		11.94		.05	
Cary.....	29.00			1.51		1.51			
Caribou.....	175.00	1.01		1.99		3.00			
Castle Hill.....	27.00			1.35		1.35		.50	
Caswell.....	20.00			1.70		1.70			
Chapman.....	14.00			1.51		1.51		.10	
Connor.....	15.00			2.92		2.92			
Crystal.....	22.00			2.56		2.56		1.10	
Cyr.....	15.00			1.09		1.09		.38	
Dyer Brook.....	13.00			2.76		2.76		.58	
E. Plantation.....	3.01								
Eagle Lake.....	12.00			1.54		1.54		2.40	
Easton.....	50.00			2.49		2.49		1.82	
Forkstown.....	7.00								
Fort Fairfield.....	150.00	1.51		3.21		4.72		1.00	
Fort Kent.....	100.00			17.52		17.52		.44	
Frenchville.....	37.00			.76		.76			
Garfield.....	5.00								
Glenwood.....	9.00			.05		.05			
Grand Isle.....	25.00			1.09		1.09			
Hamlin.....	17.00			1.24		1.24		.29	
Hammond.....	5.00			.39		.39			
Haynesville.....	18.00			1.35		1.35		.10	
Hersey.....	13.00			2.08		2.08			
Hodgdon.....	60.00			2.07		2.07			
Houlton.....	82.00	3.39		43.11		46.50		.09	
Island Falls.....	28.00			1.94		1.94		.27	
Limestone.....	50.00			2.86		2.86		.50	
Linneus.....	35.00			1.77		1.77		.18	

¹ Classification not given except as indicated in footnote.

MAINE—Continued.

TABLE 16.—Miles of public roads outside of incorporated cities, 1914—Continued.

County and town.	Total mileage, all roads.	Surfaced roads.						Graded and drained earth roads.	
		Macadam.		Gravel.	Other hard surfaced roads.	Total surfaced.	Per-centage of total surfaced.		Increase in surfaced mileage over 1909.
		Plain.	Bitumi-nous.						
Aroostook—Contd.									
Littleton.....	40.00			8.90		8.90			
Ludlow.....	22.00			3.08		3.08			
Macwahoc.....	12.00			2.22		2.22			1.93
Madawaska.....	40.00			.51		.51			.15
Mapleton.....	50.00			.98		.98			.05
Mars Hill.....	50.00			3.30		3.30			
Masardis.....	18.00			1.09		1.09			.10
Merrill.....	21.00			1.29		1.29			.63
Molunkus.....	5.00								
Monticello.....	46.00			4.89		4.89			
Moro.....	14.00			.82		.82			1.00
Nashville.....	5.00								
New Canada.....	20.00			.23		.23			.96
New Limerick.....	24.00			7.80		7.80			.22
New Sweden.....	42.00			8.26		8.26			2.14
Oakfield.....	52.00			4.04		14.04			1.33
Orient.....	17.00			1.03		.03			.37
Oxbow.....	4.00			.17		.17			
Perham.....	30.00			3.09		3.09			.61
Portage Lake.....	8.00			1.29		1.29			
Presque Isle.....	150.00			2.24		2.24			
Reed.....	21.00			.72		.72			.16
St. Agatha.....	20.00			.71		.71			
St. Francis.....	11.00			2.27		2.27			.71
St. John.....	6.00			2.06		2.06			
Sherman.....	53.00	6.21				6.21			.59
Silver Ridge.....	10.00			1.05		1.05			
Smyrna.....	20.00			2.53		2.53			.88
Stockholm.....	7.00			.55		.55			
Van Buren.....	40.00			5.93		5.93			
Wade.....	20.00			.84		.84			
Wallagrass.....	16.00			.22		.22			.33
Washburn.....	50.00			4.16		4.16			
Westfield.....	15.00			1.42		1.42			
Westmoreland.....	6.00								
Weston.....	22.00			3.03		3.03			.88
Winterville.....	6.00								
Woodland.....	60.00			4.24		4.24			
Total.....	2,248.01	12.12		214.49		226.61	10.08	67.61	25.31
Cumberland:									
Baldwin.....	50.00			1.417	0.093	1.510			.57
Bridgton.....	140.00			4.604		4.604			2.89
Brunswick.....	200.00	.871	3.959	1.534		6.364			.019
Cape Elizabeth.....	30.00			1.324	10.00	11.324			
Casco.....	50.00			7.142	20.00	27.142			.699
Cumberland.....	72.00		3.16	2.34	36.00	41.50			.081
Falmouth.....	56.00		4.054	1.929	28.00	33.983			
Freeport.....	260.00	.227	7.57	2.346		10.143			.606
Gorham.....	300.00			2.678	30.00	32.678			.414
Gray.....	63.00			7.32		7.32			
Harpswell.....	50.00			2.994		2.994			
Harrison.....	60.00			3.18		3.18			.756
Naples.....	60.00			3.296		3.296			
New Gloucester.....	115.00			3.062	25.00	28.062			.431
North Yarmouth.....	45.00			1.97		1.97			.045
Otisfield.....	72.00			2.77		2.77			.317
Pownal.....	50.00			1.549		1.549			.114
Raymond.....	60.00			.645		.645			1.97
Scarboro.....	110.00			4.266	50.00	54.266			
Sebago.....	50.00			.59		.59			
Standish.....	100.00	.701		1.239	.148	2.088			.129
Windham.....	100.00			5.034		5.034			.057
Yarmouth.....	40.00		3.47	2.277		5.747			
Total.....	2,133.00	1.799	22.213	65.506	199.241	288.759	13.86	-178.471	9.098

MAINE—Continued.

TABLE 16.—Miles of public roads outside of incorporated cities, 1914—Continued.

County and town.	Total mileage, all roads.	Surfaced roads.						Graded and drained earth roads.	
		Macadam.		Gravel.	Other hard surfaced roads.	Total surfaced.	Per- centage of total surfaced.		Increase in surfaced mileage over 1909.
		Plain.	Bitumi- nous.						
Franklin:									
Avon.....	50.00			1.69		1.69			0.18
Carthage.....	40.00			2.67	0.75	3.42			.18
Chesterville.....	60.00			1.96		1.96			.63
Coplin.....	10.00			4.35		4.35			
Crockertown.....	3.00			.26		.26			.81
Dallas.....	12.00			1.59		1.59			
Farmington.....	80.00	0.65		7.67		8.32			
Freeman.....	48.00			1.54		1.54			
Fustis.....	12.00			2.87		2.87			
Industry.....	35.00			1.88		1.88			.76
Jay.....	127.00	.88		1.52		2.40			.10
Jerusalem.....	12.00			.52		.52			.77
Kingfield.....	23.00			2.68		2.68			
Lang.....	8.00			2.02	3.00	5.02			
Madrid.....	35.00			2.73	20.00	22.73			
New Sharon.....	75.00			1.96		1.96			.12
New Vineyard.....	70.00			1.35	10.00	11.35			.08
Perkins.....	5.00			.03		.03			.04
Phillips.....	100.00			3.96	25.00	28.96			.92
Rangeley.....	27.00			1.86		1.86			.90
Rangeley (plan- tation).....	8.00			.96		.96			.48
Salem.....	20.00			.87		.87			.66
Sandy River.....	10.00			1.81		1.81			
Strong.....	50.00			4.92		4.92			.11
Temple.....	70.00			1.46	30.00	31.46			.07
Washington.....	2.00			.69		.69			
Weld.....	60.00			5.04		5.04			.08
Wilton.....	66.00			4.19		4.19			.76
Wyman.....	4.00			.26		.26			
No. 6 (Berlin) Township.....	2.00			.23		.23			.11
Total.....	1,124.00	1.53		65.54	88.75	155.82	13.86	47.32	7.76
Hancock:									
Amherst.....	20.00			1.71		1.71			
Aurora.....	20.00			1.15		1.15			
Bluehill.....	70.00			4.06	10.00	14.06			
Brooklin.....	30.00			1.94		1.94			.11
Brooksville.....	50.00			3.02		3.02			.11
Bucksport.....	100.00	.31		1.25		1.56			.08
Castine.....	30.00			2.55	15.00	17.55			.25
Cranberry Isles.....	3.50			.19		.19			
Dedham.....	25.00			.96		.96			.33
Deer Isle.....	80.00			2.00		2.00			.23
East Brook.....	16.00			1.33		1.33			
Eden.....	130.00	7.29	1.49		15.00	23.78			
Franklin.....	32.00			1.03	10.00	11.03			.14
Gouldsboro.....	35.00			1.67		1.67			.25
Hancock.....	52.00			1.74	4.00	5.74			
Isle au Haut.....	9.00			.57		.57			
Lamoine.....	28.00			2.58		2.58			.30
Long Island.....	1.00								
Mariaville.....	27.00			.64		.64			
Mount Desert.....	62.00	.53		1.57		2.10			.42
Orland.....	80.00			3.33	8.00	11.33			.37
Otis.....	14.00			1.77		1.77			
Penobscot.....	47.50			2.36		2.36			.11
Sedgwick.....	36.00			2.76	.16	2.92			
Sorrento.....	12.00			.87	4.00	4.87			
Southwest Har- bor.....	18.00			1.02		1.02			.16
Stonnington.....	20.00	.09		1.94		2.03			.14
Sullivan.....	26.00			1.57	6.00	7.57			
Surry.....	45.00			5.09	3.00	8.09			
Swans Island.....	24.00			.66		.66			.29
Tremont.....	22.00			.70		.70			.09
Trenton.....	20.00			6.82		6.82			.07
Verona.....	12.00			.96		.96			.90

MAINE—Continued.

TABLE 16.—Miles of public roads outside of incorporated cities, 1914—Continued.

County and town.	Total mileage, all roads.	Surfaced roads.							Graded and drained earth roads.
		Macadam.		Gravel.	Other hard surfaced roads.	Total surfaced.	Per- centage of total surfaced.	Increase in surfaced mileage over 1909.	
		Plain.	Bitumi- nous.						
Hancock—Contd.									
Waltham.....	22.00			1.79		1.79			
Winter Harbor.....	16.00			1.03	6.00	7.03			0.26
No. 7.....	1.00			.03		.03			
No. 8, southern division.....	2.00			.02		.02			
No. 9.....	5.00			.07		.07			
No. 10.....	6.00			.01		.01			
No. 21.....	2.50			1.06		1.06			
No. 22.....	7.00			.11		.11			
No. 28.....	2.50			.15		.15			
No. 33.....	3.00			.54		.54			
Total.....	1,264.00	8.22	1.49	64.62	81.16	155.49	12.30	34.87	4.67
Kennebec:									
Albion.....	80.00			5.46		5.46			
Belgrade.....	75.00			3.96		3.96			
Benton.....	50.00			4.16		4.16			.17
Chelsea.....	58.00			2.87		2.87			
China.....	92.00			4.08		4.08			1.50
Clinton.....	80.00			7.53		7.53			.28
Farmingdale.....	26.00	.10		6.17		6.27			
Fayette.....	60.00			1.94		1.94			
Litchfield.....	100.00			4.13		4.13			.96
Manchester.....	45.00			.62		.62			1.16
Monmouth.....	90.00	1.30		4.28		5.58			.36
Mount Vernon.....	72.00			2.63		2.63			.97
Oakland.....	72.00		.08	2.02		2.10			.63
Pittston.....	70.00			2.33	20.00	22.33			
Randolph.....	8.00		.02	1.50	4.00	5.52			
Readfield.....	66.00			6.23		6.23			.49
Rome.....	33.00			1.80		1.80			.59
Sidney.....	74.00			1.21		1.21			
Unity.....	4.00			.56		.56			.28
Vassalboro.....	100.00			7.72		7.72			
Vienna.....	34.00			2.13		2.13			2.23
Wayne.....	45.00			.77		.77			.37
West Gardiner.....	36.00			1.26		1.26			.08
Windsor.....	50.00			3.49	15.00	18.49			
Winslow.....	80.00	.43		.84	140.05	41.32			.35
Winthrop.....	62.00			5.69		5.69			.34
Total.....	1,562.00	1.83	.10	85.38	79.05	166.36	10.65	31.36	10.76
Knox:									
Appleton.....	65.00			2.27		2.27			.47
Camden.....	50.00	.25	.13	1.89		2.27			
Cushing.....	26.00			1.86		1.86			
Friendship.....	26.00			4.14		4.14			
Hope.....	40.00			5.69		5.69			.47
Hurricane Isle.....	1.00								
Matineus Isle.....	3.00								
North Haven.....	25.00			.83		.83			.22
Rockport.....	45.00		4.47	1.57	.06	6.10			
St. George.....	50.00			3.50		3.50			.29
South Thomas- ton.....	40.00			6.25		6.25			
Thomaston.....	30.00	.29		6.08		6.37			.11
Union.....	150.00			1.55	40.00	41.55			
Vinal Haven.....	50.00	.24		6.57		6.81			.07
Warren.....	100.00			7.02		7.02			
Washington.....	75.00			2.11		2.11			2.29
Total.....	776.00	.78	4.60	51.33	40.06	96.77	12.47	29.27	3.92

¹ Includes 0.05 mile of brick.

MAINE—Continued.

TABLE 16.—Miles of public roads outside of incorporated cities, 1914—Continued.

County and town.	Total mileage, all roads.	Surfaced roads.						Graded and drained earth roads.	
		Macadam.		Gravel.	Other hard surfaced roads.	Total surfaced.	Per-centage of total surfaced.		Increase in surfaced mileage over 1909.
		Plain.	Bitumi-nous.						
Lincoln:									
Alna.....	39.00			1.98		1.98			0.33
Boothbay.....	50.00			.80		.80			1.44
Boothbay Har- bor.....	23.00	2.08		.92		3.00			.32
Bremen.....	30.00			1.34		1.34			.15
Bristol.....	130.00			1.52		1.52			.35
Damariscotta.....	25.00		0.13	2.77		2.90			
Dresden.....	35.00			2.03		2.03			.38
Edgecomb.....	30.00			1.02		1.02			
Jefferson.....	100.00			10.61		10.61			
Monhegan.....	1.75								
Newcastle.....	52.00			3.57		3.57			
Nobleboro.....	40.00			7.39		7.39			
Somerville.....	30.00			2.20		2.20			
Southport.....	20.00			1.06		1.06			1.51
Waldoboro.....	120.00	.41	.08	6.57		7.06			
Westport.....	30.00			.74		.74			
Whitefield.....	75.00			1.78		1.78			.44
Wiscasset.....	55.00			6.56		6.56			.11
Total.....	885.75	2.49	.21	52.86		55.56	6.26	29.06	5.16
Oxford:									
Albany.....	50.00			1.71		1.71			.16
Andover.....	50.00			2.47	10.00	12.47			
Andover (north surplus).....	6.00			.34		.34			
Andover (west surplus).....	1.00								
Bethel.....	125.00			5.34		5.34			
Brownfield.....	75.00			2.54		2.54			
Buckfield.....	100.00			1.79		1.79			.56
Byron.....	20.00			1.72	5.00	6.72			
C.....	2.00								
C surplus.....	1.00								
Canton.....	60.00			1.91		1.91			
Denmark.....	50.00			1.47		1.47			.44
Dixfield.....	102.00			2.12		2.12			
Fryeburg.....	103.00			11.78		11.78			.18
Gilead.....	14.00			.53		.53			.46
Grafton.....	8.00			1.68		1.68			
Greenwood.....	65.00			1.17		1.17			.20
Hanover.....	10.00			.51		.51			.14
Hartford.....	80.00			.51		.51			.14
Hebron.....	55.00			.31		.31			.12
Hiram.....	90.00			.75		.75			
Lincoln.....	7.50			1.49	3.00	4.49			
Lovell.....	65.00			2.14	30.00	32.14			.34
Magalloway.....	6.00			1.20		1.20			
Mason.....	8.00			.25		.25			.44
Mexico.....	35.00			1.55		1.55			
Milton.....	14.00			.39		.39			
Newry.....	20.00			1.55		1.55			.26
Norway.....	100.00			5.30		5.30			
Oxford.....	80.00			.77	1.58	1.35			1.32
Paris.....	150.00			3.38	125.00	128.38			
Peru.....	56.00			.81		.81			
Porter.....	63.00			.65		.65			.40
Riley.....	6.00								
Roxbury.....	20.00			1.43		1.43			
Rumford.....	120.00	8.13	.25	6.41		14.79			
Stow.....	21.00			2.31		2.31			.07
Stoneham.....	25.00			2.02		2.02			.45
Sumner.....	200.00			1.68		1.68			1.29
Sweden.....	50.00			1.81		1.81			.96
Upton.....	14.00			1.00		1.00			.05
Waterford.....	100.00			3.73		3.73			.90
Woodstock.....	75.00			2.88		2.88			.23
Total.....	2,302.50	8.13	.25	81.40	173.58	263.36	11.43	57.36	9.11

¹ Includes 0.58 mile of sand-clay.

MAINE—Continued.

TABLE 16.—Miles of public roads outside of incorporated cities, 1914—Continued.

County and town.	Total mileage, all roads.	Surfaced roads.						Graded and drained earth roads.	
		Macadam.		Gravel.	Other hard surfaced roads.	Total surfaced.	Per-centage of total surfaced.		Increase in surfaced mileage over 1909.
		Plain.	Bitumi-nous.						
Penobscot:									
Alton.....	20.00			1.57	10.00	11.57			0.12
Argyle.....	12.00			.95		.95			
Bradford.....	60.00			2.34		2.34			.32
Bradley.....	12.00			2.00	8.00	10.00			
Burlington.....	22.00			1.06	11.00	12.06			
Carmel.....	60.00			8.81		8.81			.70
Carrol.....	25.00			1.69		1.69			.44
Charleston.....	62.00			1.51		1.51			.12
Chester.....	29.00			1.74	4.00	5.74			.28
Clifton.....	20.00			1.04	6.00	7.04			.11
Corinth.....	75.00			3.08		3.08			
Corinna.....	97.00			.92		.92			.81
Dexter.....	60.00	0.74		.56		1.30			.10
Dixmont.....	70.00			2.04		2.04			
Drew.....	10.00			1.19		1.19			.19
East Millinocket.....	8.00			2.27		2.27			
Eddington.....	31.00	2.04		.19		2.23			.44
Edinburg.....	6.50			1.20		1.20			2.19
Enfield.....	36.00			.83		.83			.06
Etna.....	40.00			4.71		4.71			.14
Exeter.....	100.00			.55		.55			1.38
Garland.....	50.00			.99		.99			.45
Glenburn.....	35.00			1.44	10.00	11.44			.20
Grand Falls.....	7.00			.08		.08			
Greenbush.....	40.00			2.50		2.50			.38
Greenfield.....	22.00			2.39		2.39			
Hampden.....	75.00			5.55	50.00	55.55			
Hermion.....	75.00			3.06		3.06			.52
Holden.....	50.00			2.88		2.88			
Howland.....	27.00			1.85		1.85			.93
Hudson.....	30.00			.82		.82			
Kenduskeag.....	30.00			1.90	16.00	17.90			
Kingman.....	14.00			1.55		1.55			
Lagrange.....	23.00			1.49		1.49			.36
Lakeville.....	8.00			.98		.98			.08
Lee.....	51.00			2.30		2.30			1.60
Levant.....	50.00			2.74	10.00	12.74			.19
Lincoln.....	75.00			2.54	72.32	74.86			.14
Lowell.....	15.00			.62		.62			.63
Mattamiscotis.....	6.00			.09		.09			
Mattawankeag.....	21.00			1.96	3.25	5.21			1.51
Mayfield.....	14.00			2.12		2.12			2.86
Medway.....	17.00			1.36		1.36			2.00
Milford.....	27.00			1.32		1.32			
Millinocket.....	8.00			.94		.94			.13
Mount Chase.....	20.00			1.08		1.08			
Newburg.....	36.00			4.40		4.40			.45
Newport.....	51.00		0.12	2.76		2.88			1.17
Orono.....	30.00			2.06	27.94	30.00			
Orrington.....	60.00			2.33	30.00	32.33			
Passadunkkeag.....	17.00			1.75	8.00	9.75			
Patten.....	30.00	1.84		.65	10.00	12.49			
Plymouth.....	40.00			1.12		1.12			.64
Prentiss.....	40.00			1.86		1.86			.24
Sebois.....	3.00			.23		.23			1.23
Springfield.....	40.00			1.38		1.38			2.11
Stacyville.....	10.75	.54		.58		1.12			.09
Stetson.....	50.00			2.19	30.00	32.19			
Summit.....	9.00								
Veazie.....	7.00			.35		.35			
Webster.....	7.00			.61		.61			.25
Winn.....	35.00			.58		.58			2.42
Woodville.....	25.00			.59		.59			.71
No. 2, R. 6.....	6.00								
No. 1, R. 7.....	6.00								
No. 2, R. 7.....	1.00								
A, R. 7.....	7.00								
Total.....	2,156.25	5.16	.12	108.24	306.51	420.03	19.47	51.78	28.69

MAINE—Continued.

TABLE 16.—Miles of public roads outside of incorporated cities, 1914—Continued.

County and town.	Total mileage, all roads.	Surfaced roads.						Graded and drained earth roads.	
		Macadam.		Gravel.	Other hard surfaced roads.	Total surfaced.	Per- centage of total surfaced.		Increase in surfaced mileage over 1909.
		Plain.	Bitumi- nous.						
Piscataquis:									
Abbot.....	50.00			1.53		1.53		2.87	
Atkinson.....	40.00			.93		.93		.85	
Barnard.....	10.00								
Blanchard.....	13.00			.87		.87		.05	
Bowerbank.....	6.00			.81		.81			
Brownville.....	34.00			1.34		1.34		.19	
Dover.....	75.00		0.42	7.14		7.56		.78	
Elliotsville.....	6.00								
Foxcroft.....	55.00	1.09		.23		1.32		.31	
Greenville.....	18.00			1.68	4.00	5.68			
Guilford.....	45.00			2.95	12.00	14.95		.41	
Medford.....	20.00			.98		.98		1.61	
Milo.....	60.00			2.28		2.28		.89	
Monson.....	58.00			.94		.94		3.18	
Orneville.....	55.00			.98		.98		.88	
Parkman.....	100.00			2.59		2.59		.47	
Sangerville.....	90.00			.44	3.00	3.44		.83	
Sebec.....	45.00			.65		.65		1.30	
Shirley.....	17.00			.49		.49		2.47	
Wellington.....	46.00			.68		.68		1.85	
Williamsburg.....	12.00			.42		.42		1.10	
Williamantic.....	25.00			1.13		1.13		.31	
Kingsbury.....	20.00			.13		.13		.16	
Lakeview.....	1.00								
Lilly Bay.....	7.00								
Total.....	908.00	1.09	.42	29.19	19.00	49.70	5.47	20.51	
Sagadahoc:									
Arrowsic.....	12.00			1.45		1.45			
Bath.....	30.00	1.65	.28		.30	2.23			
Bowdoin.....	74.00			2.70		2.70			
Bowdoinham.....	80.00			1.66		1.66			
Georgetown.....	47.00			.25		.25		.78	
Perkins.....	5.00								
Phippsburg.....	58.00			1.95	10.00	11.95			
Richmond.....	70.00		.15	2.13		2.28			
Topsham.....	75.00	1.64	.10	2.52		4.26			
West Bath.....	27.00			1.10		1.10			
Woolwich.....	70.00			6.90	4.00	10.90		.63	
Total.....	548.00	3.29	.53	20.66	14.30	38.78	7.07	1.41	
Somerset:									
Anson.....	100.00			1.52		1.52		.54	
Athens.....	100.00			1.77		1.77		.28	
Bingham.....	60.00			2.43		2.43			
Bald Mountain.....	2.00			.76		.76			
Bigelow.....	6.00			.13		.13		.26	
Brighton.....	50.00			.90		.90		.34	
Cambridge.....	35.00			.54		.54		.51	
Canaan.....	80.00			.49		.49		1.28	
Caratunk.....	12.00			6.10		6.10			
Carrying Place.....	2.00			.16		.16		.17	
Concord.....	35.00			1.02	15.00	16.02			
Cornville.....	75.00			.14		.14		.99	
Dead River.....	8.00			1.16		1.16			
Dennistown.....	6.00			1.63		1.63			
Detroit.....	25.00			.26		.26		1.39	
Embsen.....	50.00			.60	20.00	20.60		.05	
Fairfield.....	100.00		.05	7.52		7.57			
Flagstaff.....	10.00			.04		.04		.05	
Harmony.....	50.00			1.14		1.14		.29	
Hartland.....	50.00	.57		.19		.76		1.24	
Highland.....	12.00			.68		.68			
Jackman.....	11.50			2.95		2.95			
Johnson Moun- tain.....	6.00			.06		.06		.04	
Lexington.....	20.00			.90		.90			
Madison.....	100.00	.18	.31	.20		.69		1.33	

MAINE—Continued.

TABLE 16.—Miles of public roads outside of incorporated cities, 1914—Continued.

County and town.	Total mileage, all roads.	Surfaced roads.						Graded and drained earth roads.	
		Macadam.		Gravel.	Other hard surfaced roads.	Total surfaced.	Per-centage of total surfaced.		Increase in surfaced mileage over 1909.
		Plain.	Bitumi-nous.						
Somerset—Contd.									
Mayfield.....	10.00			1.06		1.06			
Mercer.....	42.00			1.40		1.40		0.11	
Moose River.....	6.00			2.74		2.74			
Parlin Pond.....	6.00			.37		.37		.41	
Saint Albans.....	70.00			1.79		1.79		.68	
Sandy Bay.....	6.00			.66		.66		.17	
Skownegan.....	175.00	0.53		.63	1 41.68	42.84		.72	
Moscow.....	37.00				8.00	8.00		.07	
New Portland.....	80.00			2.65		2.65		.82	
Norridgewock.....	100.00	.20		6.48		6.68		.35	
Palmyra.....	76.00			1.38		1.38		.73	
Pittsfield.....	75.00	.09		.65	2 50.14	50.88		2.38	
Pleasant Ridge.....	13.00			.13		.13			
Ripley.....	30.00			.46		.46		1.06	
Smithfield.....	32.00			1.72		1.72		.50	
Solon.....	70.00			1.09		1.09		.85	
Starks.....	80.00			.83		.83		.18	
The Forks.....	9.00			.47		.47			
West Forks.....	8.00			.54		.54			
Total.....	1,930.50	1.57	0.36	58.34	134.82	195.09	10.10	17.79	
Waldo:									
Belmont.....	29.00			.70		.70		1.87	
Brooks.....	44.00			3.31		3.31		.41	
Burnham.....	45.00			3.45		3.45		.14	
Frankfort.....	35.00	.18		2.96		3.14			
Freedom.....	56.00			1.41	5.00	6.41		.81	
Islesboro.....	50.00			1.73		1.73			
Jackson.....	45.00			2.26		2.26		.44	
Knox.....	64.00			1.88		1.88		1.66	
Liberty.....	45.00			1.06		1.06		1.60	
Lincolnville.....	70.00			1.58		1.58		.19	
Monroe.....	80.00			2.02		2.02		.41	
Montville.....	90.00			.80		.80		1.06	
Morrill.....	25.00			1.79		1.79		2.08	
Northport.....	50.00			11.02		11.02		1.85	
Palermo.....	60.00			1.17		1.17		.76	
Prospect.....	40.00			2.75		2.74			
Searsmont.....	70.00			.21		.21		2.53	
Searsport.....	50.00			3.52		3.52			
Stockton Springs.....	45.00			1.45		1.45		.65	
Swanville.....	30.00			2.82	10.00	12.82			
Thorndike.....	50.00			2.59		2.59		1.22	
Troy.....	56.00			.92		.92		.89	
Unity.....	55.00			1.01		1.01		1.57	
Waldo.....	40.00			2.09		2.09		.12	
Winterport.....	70.00			4.94	17.00	21.94		.94	
Total.....	1,288.00	.18		59.43	32.00	91.61	7.11	21.20	
Washington:									
Addison.....	55.00			3.42		3.42			
Alexander.....	35.00			1.39		1.39			
Baileyville.....	45.00			2.53		2.53			
Baring.....	13.00			2.04	3.00	5.04			
Beddington.....	9.00			.90		.90		.26	
Brockton.....	10.00			.89		.89			
Centerville.....	5.50			1.48	2.87	4.35		1.15	
Charlotte.....	30.00			1.85		1.85			
Cherryfield.....	40.00			1.62		1.62			
Codyville.....	6.00								
Columbia.....	35.00			3.79	8.00	11.79			
Columbia Falls.....	25.00			1.92	4.00	5.92			
Cooper.....	35.00			1.19		1.19		.23	
Crawford.....	14.00			1.15		1.15		.34	
Cutler.....	35.00			.22		.22			
Danforth.....	20.00			2.56	8.00	10.56			
Deblois.....	6.00			.38		.38			

¹ Includes 1.68 miles of sand-clay.² Includes 0.14 mile of concrete.

MAINE—Continued.

TABLE 16.—Miles of public roads outside of incorporated cities, 1914—Continued.

County and town.	Total mileage, all roads.	Surfaced roads.						Graded and drained earth roads.	
		Macadam.		Gravel.	Other hard surfaced roads.	Total surfaced.	Per- centage of total surfaced.		Increase in surfaced mileage over 1909.
		Plain.	Bitumi- nous.						
Washington—Con.									
Dennysville.....	12.00			1.87		1.87			
East Machias.....	36.00			1.97		1.97			
Edmunds.....	24.00			.97		.97			
Forest City.....	5.00			1.07		1.07			
Grand Lakes									
Stream.....	6.00			.38		.38			0.35
Harrington.....	40.00			1.05	3.00	4.05			
Jonesboro.....	32.00			2.02	20.00	22.02			
Jonesport.....	20.00			1.52	5.00	6.52			
Kossuth.....	6.00								
Lambert Lake..	6.00								
Lubec.....	45.00			4.76	35.00	39.76			
Machias.....	30.00			3.30	15.00	18.30			
Machiasport.....	30.00			1.90	14.00	15.90			
Marion.....	18.00			.54	4.00	4.54			
Marshfield.....	15.00			1.12	10.00	11.12			
Meddybemps.....	10.00			1.42		1.42			.97
Milbridge.....	70.00			2.55		2.55			
Northfield.....	6.00			2.36		2.36			
Pembroke.....	50.00			1.15		1.15			.56
Perry.....	60.00			3.04		3.04			
Princeton.....	24.00	0.12		2.42		2.54			.16
Robbinston.....	27.00			3.56	7.00	10.56			
Roque Bluffs.....	12.00			2.01	6.00	8.01			
Steuben.....	65.00			1.71		1.71			
Talmage.....	8.00			.65		.65			.13
Topsfield.....	20.00			2.60		2.60			
Trescott.....	28.00			1.16	25.00	26.16			
Vanceboro.....	12.00			1.99		1.99			2.49
Waite.....	9.00			.74		.74			
Wesley.....	13.00			1.40		1.40			
Whiting.....	30.00			10.86		10.86			
Whitneyville.....	12.00			.91	10.00	10.91			
No. 14.....	12.00			.12		.12			
No. 21.....	1.00								
No. 18, eastern division.....	8.00			.04		.04			
No. 19, eastern division.....	7.00			.14		.14			
No. 24, middle division.....	3.00			.14		.14			
No. 29, middle division.....	6.00			.09		.09			
No. 30, middle division.....	3.00			.16		.16			
No. 31, middle division.....	6.00			.48		.48			
No. 26, eastern division.....	1.00								
No. 10, R. 3.....	6.00								
No. 8, R. 4.....	3.00								
No. 8, R. 3.....	3.00								
Total.....	1,258.50	.12		91.50	179.87	271.49	21.57	25.49	6.64
York:									
Acton.....	60.00			1.02		1.02			
Alfred.....	70.00			1.44	20.00	21.44			
Berwick.....	125.00	1.56		2.11		3.67			
Buxton.....	125.00			1.47		1.47			
Cornish.....	52.00			1.60		1.60			
Dayton.....	35.00			8.69		8.69			
Eliot.....	40.00			2.91	20.00	22.91			
Hollis.....	100.00			1.41	30.00	31.41			
Kennebunkport	130.00		1.00	3.41	1.33	5.74			
Kennebunk.....	30.00	.13	.31	3.32		3.76			
Kittery.....	60.00	1.96	2.77	.97		5.70			.13
Lebanon.....	125.00			1.32		1.32			.13

¹ Concrete.

MAINE—Continued.

TABLE 16.—Miles of public roads outside of incorporated cities, 1914—Continued.

County and town.	Total mileage, all roads.	Surfaced roads.							Graded and drained earth roads.
		Macadam.		Gravel.	Other hard surfaced roads.	Total surfaced.	Per- centage of total surfaced.	Increase in surfaced mileage over 1909.	
		Plain.	Bitumi- nous.						
York—Continued.									
Limerick.....	60.00	-----		1.49		1.49	-----		
Limington.....	90.00	-----		1.12		1.12	-----		
Lyman.....	80.00	-----		1.36	50.00	51.36	-----		
Newfield.....	55.00	-----		1.09		1.09	-----		0.19
North Berwick.....	100.00	0.88		.49		1.37	-----		
Old Orchard.....	25.00	-----		2.28	15.00	17.28	-----		
Parsonsfield.....	100.00	-----		1.72		1.72	-----		.13
Sanford.....	135.00	.81		2.83		3.64	-----		
Shapleigh.....	75.00	-----		1.68		1.68	-----		.41
South Berwick.....	140.00	.92		10.00		10.92	-----		
Waterboro.....	112.00	-----		1.71		1.71	-----		
Wells.....	120.00	-----	2.08	2.06	¹ 15.53	19.67	-----		
York.....	150.00	-----	6.90	3.58	² 3.51	13.99	-----		
Total.....	2,194.00	6.26	13.06	61.08	155.37	235.77	10.74	32.64	1.02
Grand total...	23,536.91	55.36	43.93	1,139.36	1,523.71	2,762.36	11.74	170.27	174.68

¹ Includes 5.53 miles of concrete.² Concrete.

NEW HAMPSHIRE.

TABLE 17.—Miles of public roads outside of incorporated cities, 1914.

County and town.	Total mile- age of all roads.	Surfaced roads.							Graded and drained earth.	
		Macadam.		Gravel.	Sand- clay.	Other hard- sur- faced roads.	Total sur- faced.	Per- cent- age of total sur- faced.		In- crease in sur- faced mileage over 1909.
		Plain.	Bitu- minous.							
Belknap:										
Alton.....	100.00									1.63
Barnstead.....	110.00			1.37						108.63
Belmont.....	93.00		0.50	7.63						
Center Harbor.....	27		1.49	2.25						
Gilford.....	75			1.30						5.00
Gilmanton.....	92				2.40					
Laconia City.....	3.67		1.67	2.00						
Meredith.....	100					1 7.00				83.00
New Hampton.....	100			3.30						
Sanbornton.....	100			5.00	10.00					50.00
Tilton.....	27	3.00	10.00	2.00		2 1.00				5.00
Total.....	827.67	3.00	13.66	24.85	12.40	8.00	61.91	7.48	-28.09	
Carroll:										
Albany.....	37.00			5.40						31.60
Bartlett.....	40.00			10.00						20.00
Brookfield.....	26.00			.50						15.00
Chatham.....	21.00			6.00						9.00
Conway.....	120.00			7.80						
Eaton.....	75.00			2.50	2.50					
Effingham.....	51.00			1.62						
Freedom.....	44.50			3.00						25.00
Jackson.....	38.00			8.83						
Madison.....	50.00			3.20						
Moultonboro.....	62.00			1.20	2.00					
Ossipee.....	99.50	1.00		17.00	3.50					25.00

¹ Includes 0.20 mile of concrete.² Concrete.

NEW HAMPSHIRE—Continued.

TABLE 17.—Miles of public roads outside of incorporated cities, 1914—Continued.

County and town.	Total mile- age of all roads.	Surfaced roads.							Graded and drained earth.	
		Macadam.		Gravel.	Sand- clay.	Other hard- sur- faced roads.	Total sur- faced.	Per- cent- age of total sur- faced.		In- crease in sur- faced mileage over 1909.
		Plain.	Bitu- minous.							
Carroll—Continued.										
Sandwich.....	95.00			5.90						
Tamworth.....	100.00				11.00					
Tuftonboro.....	100.00			7.20					2.80	
Wakefield.....	98.00		6.00		7.00					
Wolfeboro.....	110.00	1.00	3.00	2.00		4.00			50.00	
Total.....	1,167.00	2.00	9.00	85.15	26.00	4.00	126.15	10.80	-21.45	
Cheshire:										
Alstead.....	70.00			4.50					65.50	
Chesterfield.....	105.00			5.00						
Dublin.....	80.00	1.00		5.75					68.25	
Fitzwilliam.....	80.00	1.30			3.00				50.00	
Gilsum.....	33.50			8.25						
Harrisville.....	60.00			4.32	2.00				5.00	
Hinsdale.....	65.00		7.00	5.00						
Jaffrey.....	87.53	.53		1.00	1.00				40.00	
Marlboro.....	57.00	4.00	.25	1.10						
Marlow.....	45.00			9.00						
Nelson.....	50.00			2.00					48.00	
Richmond.....	81.00			6.00						
Rindge.....	100.00			10.00						
Roxbury.....	22.00			8.00					1.00	
Stoddard.....	47.00			4.00						
Sullivan.....	26.00			2.00					10.00	
Surry.....	30.00			4.00					26.00	
Swanzy.....	74.00		2.50	3.50						
Troy.....	26.00		4.00	.50					15.00	
Walpole.....	106.00		.50	4.50		90.00			11.00	
Westmoreland.....	80.00			4.10					15.90	
Winchester.....	160.00		6.00	5.00						
Total.....	1,485.03	6.83	20.25	97.52	6.00	90.00	220.60	14.85	80.60	
Coos:										
Berlin.....	21.00				3.50				9.50	
Carroll.....	39.25			8.39					24.36	
Clarksville.....	33.00			15.00	5.00				10.00	
Colebrook.....	105.00			13.00		1.12			20.00	
Columbia.....	46.00			6.00						
Dalton.....	68.00			1.43		2 1.00			65.57	
Dixs grant.....										
Dummer.....	26.25			6.70					19.55	
Errol.....	25.00			14.00						
Gorham.....	28.00	3.00		10.00					15.00	
Jefferson.....	50.00			9.40					40.60	
Lancaster.....	100.00	3.50				3 10.50			26.00	
Milan.....	70.00			6.00					64.00	
North mber- land.....	30.00			11.70						
Pittsburg.....	75.00			5.00					70.00	
Randolph.....	12.00			4.00					2.00	
Shelburne.....	14.00			4.00					10.00	
Stark.....	25.00			5.25					19.75	
Stewartstown.....	65.00			10.00					45.00	
Stratford.....	24.00			10.50						
Wentworths lo- cation.....	4.00			2.00					2.00	
Whitefield.....	58.00		1.00	9.00					38.00	
Total.....	918.50	6.50	1.00	151.37	8.50	11.62	178.99	19.48	78.99	
Grafton:										
Alexandria.....	60.00			3.60						
Ashland.....	31.50			4.66		1.50				
Bath.....	99.00			8.61					50.00	
Benton.....	27.00			2.00					19.00	
Bethlehem.....	82.25		2.25	11.00					10.00	

¹ Concrete.² Clay and gravel.³ State road.

NEW HAMPSHIRE—Continued.

TABLE 17.—Miles of public roads outside of incorporated cities, 1914—Continued.

County and town.	Total mile- age of all roads.	Surfaced roads.							Graded and drained earth.	
		Macadam.		Gravel.	Sand- clay.	Other hard- surf- aced roads.	Total surf- aced.	Per- cent- age of total surf- aced.		In- crease in surf- aced mileage over 1909.
		Plain.	Bitu- minous.							
Grafton—Contd.										
Bridgewater.....	55.00			2.78					10.00	
Bristol.....	41.00		3.33	2.00						
Campton.....	62.00			8.60						
Canaan.....	103.00			4.22					75.00	
Dorchester.....	47.00								37.00	
Easton.....	23.00			5.00		3.00			6.00	
Ellsworth.....	15.00								1.00	
Enfield.....	86.00			7.00						
Franconia.....	30.00			12.00	5.00				10.00	
Grafton.....	80.00			1.50					25.00	
Groton.....	60.00			1.00					59.00	
Hanover.....	100.00	3.00		5.00						
Haverhill.....	100.00		1.61	12.50					10.00	
Hebron.....	25.00			4.00						
Holderness.....	49.00		2.95	2.50					35.00	
Landaff.....	45.00			3.20						
Lebanon.....	86.00	.25	3.00	11.50		1.25			40.00	
Lincoln.....	11.00								8.00	
Lisbon.....	80.00	1.00		12.00						
Littleton.....	95.00	2.50		6.50		1.50			60.00	
Lyman.....	60.00				.50	.50			10.00	
Lyme.....	90.00		1.00	8.31		1.00				
Monroe.....	32.00			6.00	.50				25.50	
Orange.....	25.00			2.50	2.50					
Orford.....	58.00		.50	7.30						
Piermont.....	40.00			7.00						
Plymouth.....	60.00			10.00						
Rumney.....	30.00			4.00					10.00	
Thornton.....	46.00			8.00					4.00	
Warren.....	60.00			7.00					40.00	
Waterville.....	7.00								6.00	
Wentworth.....	36.00			4.35						
Woodstock.....	27.00			12.00					15.00	
Total.....	2,063.75	6.75	14.64	207.63	8.50	5.75	243.27	11.78	95.02	
Hillsborough:										
Amherst.....	95.00			4.42	25.00				50.00	
Antrim.....	100.00	.20		1.59	5.00				70.00	
Bedford.....	75.00	.61	3.59	2.17					68.63	
Bennington.....	20.00			3.00						
Brookline.....	40.00			2.30						
Deering.....	96.00			1.60						
Francestown.....	65.00									
Goffstown.....	80.00			6.90						
Greenfield.....	56.00			1.00					55.00	
Greenville.....	16.00		.75	3.90					11.35	
Hancock.....	75.00								2.00	
Hillsboro.....	91.00	1.50	.50	3.00					30.00	
Hollis.....	75.00			2.15						
Hudson.....	66.00		4.00	2.75						
Litchfield.....	22.00			2.30					8.00	
Lyndeborough.....	70.00			2.50						
Mason.....	70.00			2.00						
Merrimack.....	110.00		8.00			2 3.00			84.00	
Milford.....	108.00	1.00	7.00							
Mont Vernon.....	60.00			1.00					16.00	
New Boston.....	125.00			1.00						
New Ipswich.....	80.00			4.50					50.00	
Pelham.....	50.00			10.00					35.00	
Peterboro.....	75.00	.80	2.00	2.00					.20	
Sharon.....	48.00			5.75						
Temple.....	51.00			2.75						
Weare.....	300.00	4.00		2.50					25.00	
Wilton.....	90.00		1.00	10.00						
Windsor.....	11.00			1.00						
Total.....	2,220.00	8.11	26.84	82.08	30.00	3.00	150.03	6.75	140.97	

¹ Concrete.² Oil and gravel.

NEW HAMPSHIRE—Continued.

TABLE 17.—Miles of public roads outside of incorporated cities, 1914—Continued.

County and town.	Total mile- age of all roads.	Surfaced roads.								Graded and drained earth.
		Macadam.		Gravel.	Sand- clay.	Other hard- sur- faced roads.	Total sur- faced.	Per- cent- age of total sur- faced.	In- crease in sur- faced mileage over 1909.	
		Plain.	Bitu- minous.							
Merrimack:										
Allenstown.....	36.00	0.56	0.76	1.06						33.62
Andover.....	80.00			.76	50.00					20.00
Boscawen.....	42.00	5.77		2.07						25.00
Bow.....	60.00	1.50		5.00						
Bradford.....	90.00		.92	3.17						
Canterbury.....	80.00			1.61	1.00	1.50				40.00
Chichester.....	50.50			3.75						.50
Danbury.....	80.00			1.25						
Dunbarton.....	70.00			1.00		2.83				56.17
Epsom.....	60.05		.05	4.00						6.00
Henniker.....	82.00			7.00						75.00
Hill.....	48.00			3.49						
Hooksett.....	90.50	.75	9.00	.75	10.00					10.00
Hopkinton.....	50.00		5.00	1.00						8.00
London.....	150.00			5.00						125.00
Newberry.....	115.00			1.75						
New London.....	75.00			4.75						70.25
Northfield.....	80.00	3.50		4.50	2.00					
Pembroke.....	65.00	3.52	3.07							2.00
Pittsfield.....	70.00		2.00	2.00						1.00
Salisbury.....	70.00				.50	2.00				47.50
Sutton.....	93.00			2.00						3.00
Warner.....	120.00		.50	5.20						.50
Webster.....	46.00			6.00						10.00
Wilmot.....	85.00			4.00						
Total.....	1,908.05	15.60	21.30	71.11	63.50	9.83	181.34	9.50	31.59	-----
Rockingham:										
Atkinson.....	20.00	1.16		1.75						
Auburn.....	80.00			3.23						
Brentwood.....	35.00			3.40						5.00
Candia.....	65.00			5.38						
Chester.....	100.00	.67		1.41						
Danville.....	22.25			2.40						
Deerfield.....	106.00			2.40						53.60
Derry.....	135.00		4.00	4.00						127.00
East Kingston.....	28.00		1.25							10.00
Epping.....	38.25		1.25	5.00	2.00	3.00				3.00
Exeter.....	29.00			24.00						
Fremont.....	28.00			2.40						25.60
Greenland.....	16.00			5.10						2.90
Hampstead.....	26.00	.75		10.00						
Hampton.....	40.00		8.00	30.00						
Hampton Falls.....	30.00			2.50						
Kensington.....	27.00			5.00						18.00
Kingston.....	48.00			3.50						
Londonderry.....	126.00			3.60	4.00					
Newcastle.....	2.50		1.17	1.33						
Newfields.....	14.00		2.40							11.60
Newington.....	20.10			2.70						
Newmarket.....	28.50	2.00				3.50				26.00
Newton.....	26.00			2.70						
North Hampton.....	33.00		2.00	22.00						9.00
Northwood.....	40.00			2.72		4.20				20.00
Nottingham.....	100.00			2.30						
Plaistow.....	42.00			5.04						15.00
Raymond.....	50.00			6.10						35.90
Rye.....	28.50		2.00	4.00						22.50
Salem.....	75.00		12.00							
Sandown.....	33.00			5.00	1.00					27.00
Seabrook.....	33.00			3.00						30.00
South Hampton.....	22.00			1.50						
Stratham.....	30.00			5.00						20.00
Windham.....	100.00		2.00	4.00	70.00					5.00
Total.....	1,677.10	4.58	36.07	182.46	77.00	2.70	302.81	18.05	77.25	-----

¹ Hardpan.² Hardpan surface.³ Concrete.⁴ Gravel, bituminous.

NEW HAMPSHIRE—Continued.

TABLE 17.—Miles of public roads outside of incorporated cities, 1914—Continued.

County and town.	Total mile- age of all roads.	Surfaced roads.							Graded and drained earth.	
		Macadam.		Gravel.	Sand- clay.	Other hard- sur- faced roads.	Total sur- faced.	Per- cent- age of total sur- faced.		In- crease in sur- faced mileage over 1909.
		Plain.	Bitu- minous.							
Strafford:										
Barrington.....	100.00			2.53					50.00	
Durham.....	54.00			5.00	15.00	20.00			4.00	
Farmington.....	80.00	2.50	1.00			¹ 1.00			5.00	
Lee.....	50.00			1.75	2.00				10.00	
Madbury.....	26.50			6.00	5.50				8.00	
Middleton.....	16.00			1.50					8.00	
Milton.....	50.00	3.00	9.00							
New Durham.....	90.00			2.20					47.80	
Rollinsford.....	40.00	2.00		3.00	1.50				31.00	
Strafford.....	85.00			3.50						
Total.....	591.50	7.50	10.00	25.48	24.00	21.00	87.98	14.87	21.66	
Sullivan:										
Acworth.....	140.00			8.40						
Charleston.....	80.00			6.00					66.00	
Claremont.....	120.00	1.00		8.60	8.00	¹ 1.00			60.00	
Cornish.....	100.00			7.33						
Croydon.....	50.00			3.00					42.00	
Goshen.....	50.00			4.32						
Grantham.....	50.00			7.40					20.00	
Langdon.....	32.00			3.50						
Lempster.....	60.00			10.00						
Newport.....	98.00		1.50	10.00		² 2.00				
Plainfield.....	120.00			5.00					50.00	
Springfield.....	90.50			.50					75.00	
Sunapee.....	60.00				7.00				20.00	
Unity.....	36.00			6.00						
Washington.....	75.00			6.00					29.00	
Total.....	1,161.50	1.00	1.50	86.05	15.00	3.00	106.55	9.17	16.55	
Grand total.....	14,020.10	61.87	154.26	1,013.70	270.90	158.90	1,659.63	11.83	211.15	

¹ Concrete.² Hardpan surface.

VERMONT.

TABLE 18.—Miles of public roads outside of incorporated cities, 1914.

County and town.	Total mileage, all roads.	Surfaced roads.				
		Mac- adam.	Gravel.	Gravel telford.	Total sur- faced.	Per- centage of total surfaced.
Addison:						
Addison.....	61.00		10.81	2.47	13.28	
Bridport.....	79.00		3.13	4.13	7.26	
Bristol.....	44.00		5.33	.58	5.91	
Cornwall.....	54.00		3.24	3.63	6.87	
Ferrisburg.....	88.00		9.62	1.49	11.11	
Goshen.....	22.00		1.60	.05	1.65	
Granville.....	48.00		5.56	.60	6.16	
Hancock.....	22.00		2.40	.35	2.75	
Leicester.....	32.00		2.22	1.59	3.81	
Lincoln.....	62.00		3.79	.28	4.07	
Middlebury.....	58.36	0.36	2.15	2.17	4.68	
Monkton.....	62.00		1.54	3.52	5.06	
New Haven.....	67.00		10.43	1.55	11.98	
Orwell.....	84.00		7.50	1.07	8.57	
Panton.....	28.00		5.97	.51	6.48	
Ripton.....	37.00		2.01	.18	2.19	
Salisbury.....	42.00		5.01	1.49	6.50	

VERMONT—Continued.

TABLE 18.—Miles of public roads outside of incorporated cities, 1914—Continued.

County and town.	Total mileage, all roads.	Surfaced roads.				
		Mac- adam.	Gravel.	Gravel telford.	Total sur- faced.	Per- centage of total surfaced.
Addison—Continued.						
Shoreham.....	90.00	.....	2.75	2.88	5.63	.....
Starksboro.....	66.00	.....	2.39	1.22	3.61	.....
Waltham.....	14.00	.....	3.98	.76	4.74	.....
Weybridge.....	35.00	.....	2.85	1.64	4.49	.....
Whiting.....	22.00	.....	1.53	1.05	2.58	.....
Total.....	1,117.36	0.36	95.81	33.21	129.38	11.57
Bennington:						
Arlington.....	43.00	.....	2.91	1.29	4.20	.....
Bennington.....	77.00	.....	2.79	3.06	5.85	.....
Dorset.....	62.00	.....	6.40	.59	6.99	.....
Glastenbury.....	3.00	.....	2.41	.....	2.41	.....
Landgrove.....	19.00	.....	1.46	.68	2.14	.....
Peru.....	32.00	.....	8.65	.22	8.87	.....
Pownal.....	77.00	.....	3.46	1.90	5.36	.....
Readsboro.....	52.00	.....	3.65	.93	4.58	.....
Rupert.....	50.00	.....	3.09	1.90	4.99	.....
Sandgate.....	41.00	.....	1.49	1.00	2.49	.....
Searsburg.....	16.00	.....	.98	.11	1.09	.....
Shaftsbury.....	97.00	.....	3.87	1.17	5.04	.....
Stamford.....	37.00	.....	3.58	.74	4.32	.....
Sunderland.....	27.00	.....	2.16	.29	2.45	.....
Winhall.....	38.00	.....	4.45	.11	4.56	.....
Woodford.....	15.00	.....	3.44	.41	3.85	.....
Total.....	686.00	.....	54.79	14.40	69.19	10.08
Caledonia:						
Barnet.....	109.00	.....	6.00	.75	6.75	.....
Burke.....	76.00	.....	7.60	.60	8.20	.....
Danville.....	135.00	.....	5.51	.72	6.23	.....
Groton.....	35.00	.....	3.86	.44	4.30	.....
Hardwick.....	79.00	.....	6.57	1.44	8.01	.....
Kirby.....	32.00	.....	3.09	.24	3.33	.....
Lyndon.....	87.00	.....	9.18	.15	9.33	.....
Newark.....	41.00	.....	5.29	.84	6.13	.....
Peacham.....	73.00	.....	3.32	1.51	4.83	.....
Ryegate.....	73.20	.....	3.57	1.85	5.42	.....
Sheffield.....	48.00	.....	3.10	.23	3.33	.....
Stannard.....	18.00	.....	.73	.26	.99	.....
Sutton.....	73.00	.....	6.85	1.21	8.06	.....
Walden.....	66.00	.....	3.98	.10	4.08	.....
Waterford.....	62.00	.....	4.99	.05	5.04	.....
Wheelock.....	55.00	.....	5.06	.50	5.56	.....
Total.....	1,062.20	.....	78.70	10.89	89.59	8.43
Chittenden:						
Bolton.....	29.00	.....	6.72	.28	7.00	.....
Charlotte.....	79.00	.....	2.38	1.02	3.40	.....
Colchester.....	64.00	.....	7.48	1.94	9.42	.....
Essex.....	59.00	.....	5.47	2.24	7.71	.....
Hinesburg.....	63.00	.....	4.82	2.49	7.31	.....
Huntington.....	45.00	.....	6.73	.56	7.29	.....
Jericho.....	64.00	.....	7.61	.30	7.91	.....
Milton.....	88.00	.....	10.40	2.12	12.52	.....
Richmond.....	55.00	.....	6.53	1.12	7.65	.....
St. George.....	6.00	.....	.46	.25	.71	.....
Shelburne.....	40.00	.....	1.34	1.14	2.48	.....
South Burlington.....	30.00	.....	.37	3.91	4.28	.....
Underhill.....	68.00	.....	7.35	.41	7.76	.....
Westford.....	59.00	.....	2.62	1.63	4.25	.....
Williston.....	57.00	.....	3.22	1.24	4.46	.....
Total.....	806.00	.....	73.50	20.65	94.15	11.68
Essex:						
Bloomfield.....	32.00	.....	5.02	1.39	6.41	.....
Brighton.....	48.00	.....	4.69	.40	5.09	.....
Brunswick.....	13.00	.....	3.92	.64	4.56	.....
Canaan.....	48.00	.....	3.34	3.04	6.38	.....
Concord.....	81.00	.....	5.71	2.56	8.27	.....

VERMONT—Continued.

TABLE 18.—Miles of public roads outside of incorporated cities, 1914—Continued.

County and town.	Total mileage, all roads.	Surfaced roads.				Per- centage of total surfaced.
		Mac- adam.	Gravel.	Gravel telford.	Total sur- faced.	
Essex—Continued.						
East Haven.....	10.00		0.48	0.73	1.21	
Granby.....	13.00		1.01	.63	1.64	
Guildhall.....	30.00		2.34	1.35	3.69	
Lemington.....	17.00		3.72	.31	4.03	
Lunenburg.....	63.00		2.48	4.77	7.25	
Maidstone.....	18.00		2.35	.21	2.56	
Norton.....	19.00		3.56	1.77	5.33	
Victory.....	30.00		1.39	.34	1.73	
Total.....	422.00		40.01	18.14	58.15	13.77
Franklin:						
Bakersfield.....	66.00		5.00	1.51	6.51	
Berkshire.....	68.00		1.37	4.77	6.14	
Enosburg.....	77.00		1.06	4.02	5.08	
Fairfax.....	79.00		2.89	2.64	5.53	
Fairfield.....	118.00		1.50	5.59	7.09	
Fletcher.....	54.00		2.62	2.72	5.34	
Franklin.....	61.00		2.20	2.33	4.53	
Georgia.....	74.00		4.39	3.58	7.97	
Highgate.....	95.00		3.52	2.88	6.40	
Montgomery.....	69.00		3.09	2.31	5.40	
Richford.....	53.00		4.77	.36	5.13	
St. Albans.....	63.00		3.51	3.73	7.24	
Sheldon.....	63.00		8.67	3.05	11.72	
Swanton.....	79.00		6.44	7.32	13.76	
Total.....	1,019.00		51.03	46.81	97.84	9.60
Grand Isle:						
Alburg.....	61.00		3.25	.80	4.05	
Grand Isle.....	42.00		4.89	.65	5.54	
Isle La Motte.....	19.00		2.87	2.89	5.76	
North Hero.....	25.00		6.68	.07	6.75	
South Hero.....	27.00		3.33	1.05	4.38	
Total.....	174.00		21.02	5.46	26.48	15.21
Lamoille:						
Belvidere.....	26.00		5.87		5.87	
Cambridge.....	86.00		8.08	.47	8.55	
Eden.....	55.00		2.90	2.90	5.80	
Elmore.....	61.00		.42	1.68	2.10	
Hyde Park.....	79.00		3.79	3.31	7.10	
Johnson.....	71.00		6.28	.69	6.97	
Morristown.....	94.00		8.54	.38	8.92	
Stowe.....	90.00		6.43	.24	6.67	
Waterville.....	25.00		1.86	.53	2.39	
Wolcott.....	68.00		3.90	1.38	5.28	
Total.....	655.00		48.07	11.58	59.65	9.10
Orange:						
Bradford.....	68.00		7.32		7.32	
Braintree.....	75.00		5.61	.81	6.42	
Brookfield.....	92.00		7.07	2.85	9.92	
Chelsea.....	81.00		6.07	.14	6.21	
Corinth.....	105.00		8.84	.05	8.89	
Fairlee.....	33.00		4.90	.07	4.97	
Newbury.....	109.00		6.09	1.62	7.71	
Orange.....	61.00		2.98	.77	3.75	
Randolph.....	109.00		6.83	2.53	9.36	
Straford.....	80.00		15.97	.40	16.37	
Thetford.....	98.00		12.26	.26	12.52	
Topsham.....	98.00		4.89	1.77	6.66	
Tunbridge.....	100.00		9.34	.24	9.58	
Vershire.....	68.00		3.91	1.00	4.91	
Washington.....	90.10		8.86	.36	9.22	
West Fairlee.....	41.00		4.91		4.91	
Williamstown.....	100.00		6.58	2.18	8.76	
Total.....	1,408.10		122.43	15.05	137.48	9.76

VERMONT—Continued.

TABLE 18.—Miles of public roads outside of incorporated cities, 1914—Continued.

County and town.	Total mileage, all roads.	Surfaced roads.				
		Mac- adam.	Gravel.	Gravel telford.	Total sur- faced.	Per- centage of total surfaced.
Orleans:						
Albany.....	74.00		5.51	0.75	6.26	
Barton Town.....	72.00		7.36	.13	7.49	
Brownington.....	53.00		4.18	.82	5.00	
Charleston.....	70.00		5.39	1.40	6.79	
Coventry.....	58.00		3.73	.19	3.92	
Craftsbury.....	83.00		5.56	.60	6.16	
Derbytown.....	96.00		7.75	.19	7.94	
Glover.....	73.00		5.69	.34	6.03	
Greensboro.....	77.00		6.68	1.25	7.93	
Holland.....	56.00		1.29	.45	1.74	
Irasburg.....	62.00		4.99	.66	5.65	
Jay.....	38.00		5.90		5.90	
Lowell.....	80.00		7.38		7.38	
Morgan.....	38.00		1.98	.35	2.33	
Newport.....	68.00		5.49	.51	6.00	
Troy.....	59.00		5.34	.12	5.46	
Westfield.....	35.00		2.11	.10	2.21	
Westmore.....	59.00		7.36	.20	7.56	
Total.....	1,151.00		93.69	8.06	101.75	8.84
Rutland:						
Benson.....	61.00		12.42	.23	12.65	
Brandon.....	74.00		3.73	4.59	8.32	
Castleton.....	66.00		3.82	2.71	6.53	
Chittenden.....	40.00		1.61	1.23	2.84	
Clarendon.....	56.00		5.34	.93	6.27	
Danby.....	100.00		4.82	1.33	6.15	
Fair Haven.....	23.00		2.78	3.06	5.84	
Hubbarton.....	38.00		2.78	1.05	3.83	
Ira.....	21.00		.53	1.07	1.60	
Mendon.....	32.00		4.08	.47	4.55	
Middletown Springs.....	37.00		2.76	.65	3.41	
Mount Holly.....	96.00		7.33	1.87	9.20	
Mount Tabor.....	12.00		1.97	.16	2.13	
Pawlet.....	59.00		4.77	1.71	6.48	
Pittsfield.....	21.00		1.51	.97	2.48	
Pittsford.....	75.00	0.29	1.61	2.01	3.91	
Poultney.....	78.00		9.63	.95	10.58	
Proctor.....	15.00	.09	2.23	1.23	3.55	
Rutland.....	33.00		4.10	2.24	6.34	
Sherburne.....	33.00		5.39	.93	6.32	
Shrewsbury.....	76.00		1.77	1.61	3.38	
Sudbury.....	37.00		3.04	.99	4.03	
Tinmouth.....	44.00		2.56	1.51	4.07	
Wallingford.....	77.00		9.20	1.62	10.82	
Wells.....	44.00		4.99	1.91	6.90	
West Haven.....	35.00		8.07	1.15	9.22	
West Rutland.....	36.00		1.37	.56	1.93	
Total.....	1,319.00	.38	114.21	38.74	153.33	11.62
Washington:						
Barre.....	82.00		4.15	1.96	6.11	
Berlin.....	74.00		5.54	2.44	7.98	
Cabot.....	76.00		3.89	2.93	6.82	
Calais.....	99.00		4.34	1.23	5.57	
Duxbury.....	41.00		5.73	.73	6.46	
East Montpelier.....	77.00	.23	2.73	2.97	5.93	
Fayston.....	40.00		3.18	.14	3.32	
Marshfield.....	74.00		1.88	1.90	3.78	
Middlesex.....	74.00		6.05	1.09	7.14	
Moretown.....	63.00		6.68	1.13	7.81	
Northfield.....	85.00		5.22	.87	6.09	
Plainfield.....	46.00		1.65	1.01	2.66	
Roxbury.....	61.00		3.23	1.23	4.46	
Waitsfield.....	43.00		4.32	.30	4.62	
Warren.....	66.00		4.98	.50	5.48	
Waterbury.....	75.00	.05	4.73	1.34	6.12	
Woodbury.....	70.00		5.21	.55	5.76	
Worcester.....	45.00		2.65	.59	3.24	
Total.....	1,191.00	.28	76.16	22.91	99.35	8.34

VERMONT—Continued.

TABLE 18.—Miles of public roads outside of incorporated cities, 1914—Continued.

County and town.	Total mileage, all roads.	Surfaced roads.				Per- centage of total surfaced.
		Mac- adam.	Gravel.	Gravel telford.	Total sur- faced.	
Windham:						
Athens.....	22.00		1.96	0.67	2.63	
Brattleboro.....	95.00	0.40	6.18	1.25	7.83	
Brookline.....	19.00		2.00	.06	2.06	
Dover.....	51.00		7.26	.77	8.03	
Dummerston.....	73.00		5.63	.20	5.83	
Grafton.....	61.00		2.36	.74	3.10	
Guilford.....	88.00		5.42	.80	6.22	
Halifax.....	82.00		6.06	.36	6.42	
Jamaica.....	86.00		6.30		6.30	
Londonderry.....	71.00		6.81	1.96	8.77	
Marlboro.....	80.00		7.79	.54	8.33	
Newfane.....	82.00		6.92		6.92	
Putney.....	64.00	.13	4.60	.60	5.33	
Rockingham.....	79.00	.39	6.88	.98	8.25	
Somerset.....	10.00		1.45		1.45	
Stratton.....	24.00		4.09	.10	4.19	
Townshend.....	79.00		6.89	1.07	7.96	
Vernon.....	29.00		4.45	.02	4.47	
Wardsboro.....	68.00		3.23	.14	3.37	
Westminster.....	80.00		7.19	.02	7.21	
Whitingham.....	91.00		6.52	.88	7.40	
Wilmington.....	77.00		6.35	.61	6.96	
Windham.....	46.00		5.84	1.79	7.63	
Total.....	1,457.00	.92	122.18	13.56	136.66	9.37
Windsor:						
Andover.....	47.00		3.49	.30	3.79	
Baltimore.....	8.00		.51	.34	.85	
Barnard.....	99.00		8.93	.29	9.22	
Bethel.....	93.00		5.80	.92	6.72	
Bridgewater.....	64.00		6.18	.31	6.49	
Cavendish.....	59.00		5.12	1.31	6.43	
Chester.....	104.00		4.70	1.41	6.11	
Hartford.....	130.00		16.86	.21	17.07	
Hartland.....	108.00		11.17	.42	11.59	
Ludlow.....	67.00		5.90	1.33	7.23	
Norwich.....	104.00		13.51		13.51	
Plymouth.....	80.00		6.79	.11	6.90	
Pomfret.....	90.00		10.71		10.71	
Reading.....	73.00		5.73	.23	5.96	
Rochester.....	80.00		8.42	.95	9.37	
Royalton.....	91.00		8.34		8.34	
Sharon.....	64.00		14.14	.06	14.20	
Springfield.....	110.00		13.44		13.44	
Stockbridge.....	66.00		2.83	1.75	4.58	
Weathersfield.....	99.00		8.42	1.11	9.53	
Weston.....	58.00		3.38	2.61	5.99	
West Windsor.....	54.00		4.10	.52	4.62	
Windsor.....	33.00		5.35	1.03	6.38	
Total.....	1,781.00		173.82	15.21	189.03	10.61
Grand total.....	14,248.66	1.94	1,165.42	274.67	1,442.03	10.12

MASSACHUSETTS.

TABLE 19.—*Miles of public roads outside of incorporated cities, 1914.*

County and town.	Total mileage, all roads.	Surfaced roads.							Graded and drained earth roads.
		Macadam.		Gravel.	Pave- ment. ¹	Total sur- faced.	Per- centage of total sur- faced.	Increase in sur- faced mileage over 1909.	
		Plain.	Bitumi- nous.						
Barnstable:									
Barnstable.....	190.00	30.00	24.00	4.00					82.00
Bourne.....	106.50	2.00	7.50	25.00					52.00
Brewster.....	57.00	12.00	8.00	7.00					
Chatham.....	50.00	1.50	7.00						29.50
Dennie.....	65.00	1.00	16.50						33.50
Eastham.....	45.00		6.50						32.50
Falmouth.....	160.00		38.00	94.00					28.00
Harwich.....	80.00	3.50	12.50						13.00
Mashpee.....	55.00			4.50					42.50
Orleans.....	33.00		10.00						6.00
Provincetown.....	12.00	3.00	3.00						6.00
Sandwich.....	80.00		5.50	15.00					49.50
Truro.....	70.00		7.00	8.00					40.00
Wellfleet.....	42.50	1.50	8.00	5.00					8.00
Yarmouth.....	69.00	1.00	18.00						20.00
Total.....	1,115.00	55.50	171.50	162.50		389.50	34.90	91.26	442.50
Berkshire:									
Adams.....	52.21		3.66	18.18	0.89				29.48
Alford.....	21.00			10.00					
Becket.....	81.00		9.00						52.00
Cheshire.....	68.00		4.50	1.20					.80
Clarksburg.....	15.00		1.20	5.00					5.80
Dalton.....	35.00	3.50	4.00	10.00					
Egremont.....	36.00			16.00					
Florida.....	51.50			11.50					
Great Barrington.....	82.00	2.00	2.75	51.12	.88				
Hancock.....	25.50		3.00	17.50					
Hinsdale.....	33.50	1.50		1.00					1.00
Lanesboro.....	53.00		2.50	6.00					30.50
Lee.....	61.00	5.50	4.10	26.80					24.60
Lenox.....	55.75		17.75	16.00					16.00
Monterey.....	48.00			4.00					34.00
Mount Washington.....	21.00			1.00					18.00
New Ashford.....	13.00			3.00					7.00
New Marlboro.....	102.00			10.00					85.00
Otis.....	60.00			3.50					3.50
Peru.....	45.00								3.00
Richmond.....	63.00	3.00		10.00					40.00
Sandisfield.....	100.00	4.00							
Savoy.....	63.25			2.25					55.00
Sheffield.....	100.00		3.00	31.00					
Stockbridge.....	44.20	10.00	1.00	33.20					
Tyringham.....	29.00	1.00		9.00					
Washington.....	51.00			2.00					1.00
West Stockbridge.....	45.00	2.00		23.00					10.00
Williamstown.....	67.00		3.00	15.40	.60				27.00
Windsor.....	82.75	5.00		1.25					
Total.....	1,604.66	37.50	59.46	338.90	2.37	438.23	27.30	58.59	443.68
Bristol:									
Acushnet.....	31.25	14.35	3.40						13.50
Berkley.....	49.00		1.00	44.00					4.00
Dartmouth.....	112.75	42.00	4.75	3.00					60.50
Dighton.....	45.00		9.00						36.00
Easton.....	63.00	17.20	.80	39.00	4.00				2.00
Fairhaven.....	38.00	8.00	1.50	10.00	.50				8.00
Freetown.....	67.00	8.50	4.00	46.50					
Mansfield.....	65.00	1.50	2.50	33.00					17.00
North Attleboro.....	91.70	15.00	12.00	15.00	.65				29.05
Norton.....	65.00		7.00	56.75					.50
Raynham.....	50.00	1.50	3.00	40.50					
Rehoboth.....	107.50	2.50	6.50	78.50					
Seekonk.....	52.00	6.00	5.50	32.00					5.00
Somerset.....	27.00	10.00	.50	16.50					
Swansea.....	49.50	1.50	9.75	28.25					9.00
Westport.....	110.00	35.00		16.00					51.75
Total.....	1,023.70	163.05	71.20	459.00	5.15	698.40	68.20	-165.04	236.30

¹ Report says pavement; classification not given.

MASSACHUSETTS—Continued.

TABLE 19.—Miles of public roads outside of incorporated cities, 1914—Continued.

County and town.	Total mileage, all roads.	Surfaced roads.							Graded and drained earth roads.
		Macadam.		Gravel.	Pave- ment.	Total sur- faced.	Per- centage of total sur- faced.	Increase in sur- faced mileage over 1909.	
		Plain.	Bitumi- nous.						
Dukes:									
Chilmark.....	34.50		8.00						14.50
Edgartown.....	30.25	3.25	2.50	1.50	1.00				2.00
Gay Head.....	3.25		.50						2.75
GasnoId.....	1.00			1.00					
Oak Bluffs.....	31.00		3.00		20.00				3.00
Tisbury.....	14.10	2.10	5.00	3.00					4.00
West Tisbury.....	49.00	5.50	3.50						30.00
Total.....	163.10	10.85	22.50	5.50	21.00	59.85	36.70	8.79	56.25
Essex:									
Amesbury.....	70.40	7.50	2.50	18.00	.40				42.00
Andover.....	88.00	1.75	4.25	80.00					
Boxford.....	50.00			20.00					30.00
Danvers.....	90.00	5.00	1.00	76.00					5.00
Essex.....	22.30		1.50	17.80					2.00
Georgetown.....	32.00	1.00	.75	24.00					
Groveland.....	30.00		6.10	22.40					
Hamilton.....	38.00		5.00	29.00					
Ipswich.....	60.00		6.00	48.00					
Lynnfield.....	20.00			15.00					5.00
Manchester.....	17.50		10.00	7.50					
Marblehead.....	34.00	1.50	6.00	2.50					
Merrimac.....	35.00		2.50	21.00					10.00
Methuen.....	90.00	14.00	40.00	26.00					
Middleton.....	31.00		3.00	28.00					
Nahant.....	11.00	2.75	3.25	3.00					2.00
Newbury.....	43.00		4.25	28.00					5.75
North Andover.....	100.00	15.00	10.00	51.90	3.10				
Peabody.....	54.00	7.00	.75	42.50	.50				
Rockport.....	27.00	7.00	3.12	4.38					.50
Rowley.....	40.00		3.64	19.36					12.00
Salisbury.....	35.00		4.50	26.50					
Saugus.....	81.00	.75	2.50	50.00					
Swampscott.....	28.50	7.00	3.50	9.00	1.00				2.50
Topsfield.....	41.00			10.00					31.00
Wenham.....	20.00		3.00	17.00					
West Newbury.....	44.00	.50	5.50	38.00					
Total.....	1,232.70	70.75	132.61	734.84	5.00	943.20	76.50	77.48	147.75
Franklin:									
Ashfield.....	86.00			4.00					73.00
Barnardston.....	59.50			52.50					
Buckland.....	45.00	4.33		10.00					25.67
Charlcmont.....	55.00		1.40	14.60					
Colrain.....	86.00		2.00	10.00					67.00
Conway.....	90.00			2.90	.10				84.00
Deerfield.....	68.00		8.00	20.00					40.00
Erving.....	28.17	.17	10.12						17.88
Gill.....	34.00			3.00					24.00
Greenfield.....	64.32		21.23	8.73	.18				34.18
Hawley.....	55.00			3.50					6.50
Heath.....	55.00			3.50					30.00
Leverett.....	40.00			4.00					32.00
Leyden.....	32.00			3.50					22.50
Monroe.....	24.00			4.00					
Montague.....	95.00	8.25	5.75	40.00					41.00
New Salem.....	80.00			4.67					35.33
Northfield.....	75.00	1.50	4.25	48.50					
Orange.....	80.00	1.00	5.00	8.75					65.25
Rowe.....	48.00			2.50					30.50
Shelburne.....	47.31	1.10	1.21	20.00					17.69
Shutesbury.....	50.00			3.00					4.00
Sunderland.....	38.75	4.50	2.00	6.00					26.25
Warwick.....	70.00			5.00					50.00
Wendell.....	58.00			4.00					24.00
Whately.....	43.00	4.00	4.00	5.00					8.00
Total.....	1,507.05	24.85	64.96	291.65	.28	381.74	25.30	215.72	758.75

MASSACHUSETTS—Continued.

TABLE 19.—Miles of public roads outside of incorporated cities, 1914—Continued.

County and town.	Total mileage, all roads.	Surfaced roads.						Graded and drained earth roads.	
		Macadam.		Gravel.	Pave- ment.	Total sur- faced.	Per- centage of total sur- faced.		Increase in sur- faced mileage over 1909.
		Plain.	Bitumi- nous.						
Hampden:									
Agawam.....	57.50		11.50	26.00					20.00
Blandford.....	98.00		4.50						44.50
Brimfield.....	66.00	4.00		4.00					57.00
Chester.....	80.00		7.00	3.00					50.00
East Longmeadow.....	39.50	4.50		4.00					31.00
Granville.....	80.00			5.00					70.00
Hampden.....	32.00			12.00					17.00
Holland.....	30.00								3.00
Longmeadow.....	34.50	.45	2.20	11.25	1.10				
Ludlow.....	70.00	.20		2.00					59.80
Monson.....	127.50	5.00	1.50	1.00					100.00
Montgomery.....	30.00			8.00					17.00
Palmer.....	95.00	3.50	2.25	20.00	.25				67.00
Russell.....	27.00		2.66	11.00					9.34
Southwick.....	60.00			11.00					49.00
Tolland.....	41.00	1.00		7.00					26.00
Wales.....	29.00			5.00					18.00
West Springfield.....	97.00	5.00	30.00	20.00	2.00				40.00
Westfield.....	102.00	9.37	5.83	24.80					42.00
Wilbraham.....	47.00		5.00	5.00					26.00
Total.....	1,243.00	33.02	72.44	180.05	3.35	288.86	23.20	-11.44	746.64
Hampshire:									
Amherst.....	75.00	3.50	2.75	62.75					
Belchertown.....	140.00	3.25		3.00					83.75
Chesterfield.....	56.00			3.00					
Cummington.....	60.00			5.00					55.00
Easthampton.....	56.00	8.00	2.11	.40					44.50
Enfield.....	40.00			5.50					14.50
Goshen.....	32.00		2.50	2.00					21.50
Granby.....	55.25	5.75							48.50
Greenwich.....	42.00			1.50					
Hadley.....	62.00	2.50	5.00	3.00					49.50
Hatfield.....	56.50	6.00	4.00	4.50					24.00
Huntington.....	50.00		2.50	7.50					
Middlefield.....	35.00			5.00					20.00
Pelham.....	38.00			2.50					28.50
Plainfield.....	42.50			2.00					34.00
Prescott.....	44.00			4.00					30.00
South Hadley.....	50.00	7.00	7.50	27.00					8.50
Southampton.....	75.00	.75		2.75					61.50
Ware.....	92.00	5.80	1.00	40.00	.20				39.00
Westhampton.....	49.00			5.00					35.00
Williamsburg.....	43.00	4.00		3.00					13.00
Worthington.....	75.00			2.00					50.00
Total.....	1,268.25	46.55	28.35	193.90	.20	269.00	21.20	21.73	658.25
Middlesex:									
Acton.....	76.00	5.00	5.00	20.00					45.00
Arlington.....	69.50	13.60	9.00	23.40	.10				15.40
Ashby.....	70.00	1.53	3.56						54.91
Ashland.....	46.25	.50	2.75	42.00					
Ayer.....	30.00		1.00	9.00					10.00
Bedford.....	29.70	9.00	.60	11.70					3.90
Belmont.....	30.20	5.80	4.50	18.70					
Billerica.....	66.00	3.00	2.00	37.67					
Boxboro.....	29.25	2.00	1.25	14.00					7.00
Burlington.....	41.25	2.75	5.00	28.50					
Carlisle.....	60.00			18.00					12.00
Chelmsford.....	92.00		3.75	88.25					
Concord.....	87.83		12.50	60.00	.33				5.00
Dracut.....	65.00	4.00	4.50	31.50					22.00
Dunstable.....	35.00			14.00					12.00
Framington.....	100.00		7.00	50.00					30.00
Groton.....	71.00	3.00	1.50	59.50					
Holliston.....	54.00		5.00	9.00					35.00
Hopkinton.....	69.00	2.00		33.00					24.00
Hudson.....	43.00	1.00	2.00	30.00					
Lexington.....	80.00	18.00	12.00	35.00					
Lincoln.....	43.00	5.00	3.00	20.00					10.00
Littleton.....	46.00	1.25	4.75	40.00					
Maynard.....	25.00		5.00	14.00					1.00
Natick.....	102.00	4.75	3.25	86.00					8.00
North Reading.....	36.25		11.25	15.00					7.00

MASSACHUSETTS—Continued.

TABLE 19.—Miles of public roads outside of incorporated cities, 1914—Continued.

County and town.	Total mileage, all roads.	Surfaced roads.						Graded and drained earth roads.	
		Macadam.		Gravel.	Pave- ment.	Total sur- faced.	Per- centage of total sur- faced.		Increase in sur- faced mileage over 1909.
		Plain.	Bitumi- nous.						
Middlesex—Continued.									
Pepperell.....	75.00	1.25	2.00	4.00					67.75
Reading.....	48.00	3.00	9.50	21.00					11.50
Sherborn.....	50.00			43.00					7.00
Shirley.....	42.00	1.14		4.36					28.50
Stoneham.....	37.50	.90	3.10	17.00					16.50
Stow.....	45.00			25.00					18.00
Sudbury.....	60.00		5.00	40.00					15.00
Tewksbury.....	65.00	1.00	8.00	48.00					
Townsend.....	80.00		6.00	8.00					58.00
Tyngsboro.....	41.00	7.00		12.00					11.00
Wakesfield.....	48.00	9.20	4.50	34.00	.30				
Watertown.....	56.25	18.50	17.50	20.10	.15				
Wayland.....	52.00		2.50	36.00					8.50
Westford.....	90.00			90.00					
Weston.....	49.00	2.00	7.75	39.25					
Wilmington.....	52.50		4.50	48.00					
Winchester.....	43.00		25.60	12.90					
Total.....	2,431.48	128.17	206.16	1,350.33	.88	1,685.54	69.30	-193.43	438.41
Nantucket: Nantucket.....	114.00		7.50			7.50	6.60	- 7.98	29.00
Norfolk:									
Avon.....	10.00	.50	.50	8.00					
Bellingham.....	44.00	.82	3.18	9.25					30.75
Braintree.....	50.00		17.50	32.50					
Brookline.....	71.09	13.35	46.43	10.05	1.26				
Canton.....	40.00		3.25	36.75					
Cohasset.....	26.11		11.65	14.46					
Dedham.....	55.50	20.00	7.00	26.00	.50				2.00
Dover.....	38.19		2.19	36.00					
Foxboro.....	52.00	3.50	3.50	45.00					
Franklin.....	76.00	1.00	5.77	11.00					43.23
Holbrook.....	20.00		1.75	18.25					
Medfield.....	40.00			36.00					
Medway.....	40.00		3.00	37.00					
Millis.....	34.00			17.00					
Milton.....	55.00	15.00	16.00	24.00					
Needham.....	45.00		17.00	26.00					
Norfolk.....	46.45		1.45	10.00					35.00
Norwood.....	40.00	2.50	4.00	32.00					1.50
Plainville.....	35.00	.10	2.30						27.60
Randolph.....	30.75	.25	2.50	25.00					
Sharon.....	68.67	.67		30.00					28.00
Stoughton.....	56.50		5.50	10.00					40.00
Walpole.....	65.00		5.00	60.00					
Wellesley.....	55.00	10.00	10.00	30.00					5.00
Westwood.....	32.00		2.00	27.00					
Weymouth.....	75.00	3.00	8.00	64.00					
Wrentham.....	63.00		6.00						54.00
Total.....	1,264.26	70.69	185.47	682.26	1.76	940.18	74.40	- 98.14	260.08
Plymouth:									
Abington.....	58.00		5.00	40.00					13.00
Bridgewater.....	70.69	5.00	6.25	42.00					15.75
Carver.....	67.00	13.00		24.00					10.00
Duxbury.....	90.00		6.50	60.00					23.50
East Bridgewater.....	49.50	5.00		44.50					
Halifax.....	32.25	2.25		15.00					15.00
Hanover.....	45.00	3.00		21.00					21.00
Hanson.....	34.00	8.00		26.00					
Hingham.....	84.00	1.00	8.71	52.04					14.00
Hull.....	25.70		4.20	20.50					1.00
Kingston.....	40.00		5.00	8.00					24.00
Lakeville.....	65.00	2.50	10.75	5.00					46.75
Marion.....	25.38	10.25	10.38						4.00
Marshfield.....	77.00	1.50	9.00	30.00					21.50
Mattapoisett.....	33.00	3.25	2.50	27.25					
Middleboro.....	196.00	4.00	8.40	78.60					54.00
Norwell.....	50.60		.33	4.67					44.60
Pembroke.....	57.00	1.50	.50	44.50					5.50
Plymouth.....	208.00	3.51	9.02	40.47					45.00
Plympton.....	34.00			15.00					15.00
Rochester.....	85.00	8.00	5.00	2.00					30.00

MASSACHUSETTS—Continued.

TABLE 19.—Miles of public roads outside of incorporated cities, 1914—Continued.

County and town.	Total mileage, all roads.	Surfaced roads.						Graded and drained earth roads.	
		Macadam.		Gravel.	Pave- ment. ¹	Total sur- faced.	Per- centage of total sur- faced.		Increase in sur- faced mileage over 1909.
		Plain.	Bitumi- nous.						
Plymouth—Continued.									
Rockland.....	36.50	4.75	3.10	25.65					
Scituate.....	56.00		13.00	43.00					
Wareham.....	135.00	6.00	18.00	25.00	0.50				20.00
West Bridgewater.....	44.00		4.00	40.00					
Whitman.....	34.75	3.00	5.00	23.25					2.00
Total.....	1,731.68	85.51	134.64	758.18	.50	978.83	56.50	-453.61	424.85
Suffolk: Winthrop.....									
	26.00	.80	6.20	19.00		26.00	100.00	- 37.60	
Worcester:									
Ashburnham.....	125.00								100.00
Athol.....	86.00		4.60	3.00	.78				77.62
Auburn.....	47.00		5.00						42.00
Barre.....	122.00	14.00	3.00	5.00					75.00
Berlin.....	37.00			23.50					
Blackstone.....	52.00		3.73	29.27					
Bolton.....	55.00			55.00					
Boylston.....	31.50	4.50		5.00					17.00
Brookfield.....	60.50	.50	6.00						54.00
Charlton.....	130.00	1.10	7.90	.25					107.75
Clinton.....	35.28	12.60	1.58	18.10					3.00
Dana.....	50.00			3.50					16.50
Douglas.....	75.00	4.20	2.20	.60					68.00
Dudley.....	65.00	.50	2.25	4.75					52.50
Gardner.....	75.00	2.00	3.50	65.90	.10				.50
Grafton.....	73.00	2.50	5.18	8.50					45.82
Hardwick.....	85.82			5.00	.82				
Harvard.....	66.00	3.00	3.00	2.00					32.00
Holden.....	87.00	5.50		.50					
Hopedale.....	16.60	3.46	2.61	9.03					1.50
Hubbardston.....	80.00			5.00					65.00
Lancaster.....	70.00	2.00	1.25	51.75					
Leicester.....	68.50	5.50		32.00					31.00
Leominster.....	99.44	10.00	9.13	48.00	.12				22.19
Lunenburg.....	80.00		6.00	62.00					2.00
Mendon.....	44.00			5.00					20.00
Millford.....	80.00	4.00	8.00	30.00					38.00
Millbury.....	50.00	1.40	4.60		.15				41.85
New Braintree.....	55.00	.50		.75					53.75
North Brookfield.....	67.00	5.00							62.00
Northboro.....	55.00		5.00	25.00					
Northbridge.....	43.00		3.00	30.00					
Oakham.....	50.00			10.00					10.00
Oxford.....	75.00		4.25	15.00					46.75
Paxton.....	37.00		3.50	2.00					28.00
Petersham.....	70.00			4.50					21.00
Phillipston.....	46.00		5.50	4.50					26.00
Princeton.....	77.00	3.50		5.00					65.00
Royalston.....	85.75			1.25					
Rutland.....	85.00		1.12	2.00					48.88
Shrewsbury.....	62.00		5.00	18.00					34.00
Southboro.....	60.00	3.00	3.69	52.31					1.00
Southbridge.....	69.50	1.00	1.50	3.00	1.50				59.50
Spencer.....	92.00	1.60	5.40		.60				77.40
Sterling.....	81.00		8.35	2.00					70.65
Sturbridge.....	90.00		4.00	71.00					
Sutton.....	92.00	1.50	2.25	27.50					60.75
Templeton.....	88.50	2.00	6.50	10.00					67.50
Upton.....	64.00			50.00					9.00
Uxbridge.....	81.00	1.00	4.75	2.00					65.25
Warren.....	72.00		8.00	20.00					38.00
Webster.....	36.13	3.50	10.50	11.00	.13				11.00
West Boylston.....	42.00	5.00	3.00	30.00					4.00
West Brookfield.....	55.00		4.00	2.00					43.00
Westboro.....	65.00	1.00	.25	61.25					2.50
Westminster.....	94.00		5.25	82.75					
Winchendon.....	120.00	1.70		72.00					19.30
Total.....	3,956.52	107.06	174.34	1,113.46	4.20	1,399.06	35.40	536.38	1,811.46
Grand total.....	18,681.40	834.30	1,337.33	6,289.57	44.69	8,505.89	45.53	42.71	6,453.92

RHODE ISLAND.

TABLE 20.—Miles of public roads outside of incorporated cities, 1914.

County and town.	Total mileage, all roads.	Surfaced roads.						Graded and drained earth roads.
		Macadam.		Gravel.	Total sur- faced.	Per- centage of total surfaced.	Increase in sur- faced mileage over 1909.	
		Plain.	Bitumi- nous.					
Bristol:								
Barrington.....	28.60	3.53	5.37	19.70	28.60	63.35	5.96	20.40
Bristol.....	37.00	4.63	5.33	5.00	14.96			8.00
Warren.....	25.25	5.16	2.84	6.00	14.00			
Kent:								
Coventry.....	126.00	18.45	2.51	10.00	30.96	25.50	36.54	25.00
East Greenwich.....	65.00	2.00	.50	13.00	15.50			12.00
Warwick.....	96.00	7.50	13.51	10.00	31.01			22.00
West Greenwich.....	94.00	5.37	.....	3.00	8.37			10.00
West Warwick.....	34.00	8.00	.....	12.00	20.00			6.00
Newport:								
Jamestown.....	18.00	5.00	1.00	12.00	18.00	39.78	10.84	.....
Little Compton.....	47.00	6.59	2.27	.....	8.86			10.00
Middletown.....	36.00	10.00	2.00	4.00	16.00			20.00
New Shoreham.....	31.00	5.00	1.00	.....	6.00			25.00
Portsmouth.....	31.00	12.00	.....	5.50	17.50			.....
Tiverton.....	55.00	16.15	4.23	.....	20.38	29.37	-261.08	10.00
Providence:								
Burrillville.....	120.00	17.00	3.63	6.00	26.63			20.00
Cumberland.....	90.00	18.00	7.00	2.00	27.00			60.00
East Providence.....	60.65	17.00	11.65	5.00	33.65			12.00
Foster.....	108.00	3.98	2.44	4.00	10.42			17.00
Gloucester.....	104.50	7.01	8.09	.....	15.10			20.00
Johnston.....	55.00	18.01	4.71	12.00	34.72			5.00
Lincoln.....	51.00	5.78	.48	20.50	26.76			7.00
North Providence.....	21.50	7.48	1.57	8.00	17.05			.....
North Smithfield.....	54.50	7.60	4.82	6.00	18.42			10.00
Smithfield.....	70.00	8.00	.....	12.00	20.00			10.00
South Scituate.....	118.50	10.97	.....	10.00	20.97			22.00
Washington:								
Charleston.....	55.00	11.07	1.08	.....	12.15	32.51	-140.91	.....
Exeter.....	102.00	9.76	.....	5.00	14.76			7.00
Hopkinton.....	87.00	12.00	.....	.....	12.00			.....
Narragansett.....	30.00	8.26	10.44	6.00	24.70			.....
North Kingston.....	77.00	17.23	4.27	10.00	31.50			10.00
Richmond.....	76.50	14.25	.....	.....	14.25			16.00
South Kingston.....	97.00	21.14	7.66	10.50	39.30			12.00
Westerly.....	67.70	29.00	2.00	12.90	43.90	31.65	-348.65	.....
Total.....	2,169.70	352.92	110.40	230.10	693.42			396.40

¹ Includes 3 miles of granite block.

CONNECTICUT.

TABLE 21.—Miles of public roads outside of incorporated cities, 1914.

County and town.	Total mileage, all roads.	Surfaced roads.								Graded and drained earth roads.	
		Macadam.		Gravel.	Sand-clay.	Brick, paved.	Concrete.	Total surfaced.	Percentage of total surfaced.		Increase in surfaced mileage over 1909.
		Plain.	Bituminous.								
Fairfield:											
Bethel.....	40.00	2.61		15.85	15.77			34.23			0.77
Brookfield.....	62.00	1.32		5.00				6.32			2.66
Danbury.....	150.00	3.45		58.78				62.23			60.00
Darien.....	64.32	1.00	3.87	5.00			0.45	10.32			54.00
Easton.....	70.00	2.20	1.90	5.52				4.62			4.13
Fairfield.....	158.00	10.58	4.78	20.00				35.36			75.15
Greenwich.....	150.00	6.94	5.87	67.00				79.81			70.19
Huntington.....	110.00	5.00		12.00				17.00			40.61
Monroe.....	100.00	.19		2.63				2.82			4.54
New Canaan.....	85.00	5.85	1.32	20.00				27.17			
New Fairfield.....	48.00			5.00	1.00			6.00			30.00
Newtown.....	400.00	3.68		11.32				15.00			15.00
Redding.....	90.00	1.34		1.90				3.24			12.51
Ridgefield.....	200.00	4.91	1.10	11.40				17.41			3.71
Sherman.....	57.00	.80		1.00	30.00			31.80			1.94
Stamford.....	125.00	14.04	.97	30.00	22.00			67.01			20.00
Stratford.....	84.50	2.89	4.17	12.75	45.00	.02		64.83			1.22
Trumbull.....	60.00	3.34	5.26	3.06				11.66			10.15
Weston.....	70.00			4.00				4.00			20.00
Westport.....	100.00	8.82	4.39	.31	80.00	.15	.54	94.21			
Wilton.....	75.00			16.01	2.00			18.01			3.72
Total.....	2,298.82	78.96	33.63	303.53	195.77	.17	.99	613.05	26.66	111.26	430.30
Hartford:											
Avon.....	58.00	10.00		.57				10.57			28.22
Berlin.....	154.00	10.06		6.00	10.00			26.06			25.63
Bloomfield.....	95.00	20.00						20.00			15.00
Burlington.....	75.00	.93		4.00				4.93			2.19
Canton.....	60.00	2.66		9.04				11.70			15.73
East Granby.....	40.00	5.00		10.00				15.00			12.00
East Hartford.....	70.00	14.44	5.57			.03	.85	20.89			20.00
East Windsor.....	125.00	7.00	1.95	9.00				17.95			
Enfield.....	75.00	15.00	1.45	20.00		.04	.05	36.54			20.00
Farmington.....	240.00	17.00	6.62		40.00			63.62			110.00

Glastonbury.....	120.00	9.00	2.36	7.00	10.00		18.36			25.11
Granby.....	142.00	9.00	.45				19.45			70.00
Hartland.....	80.00									17.09
Manchester.....	89.00	11.58		30.00		1.93	43.51			25.00
Marlboro.....	40.00	2.23					2.23			20.00
Newington.....	30.00	14.58	.13		10.00		24.71			
Plainville.....	22.00	6.73	.75	4.00	2.00		13.48			3.50
Rocky Hill.....	40.00	6.95					6.95			25.00
Simsbury.....	90.00	20.14	1.69	5.01			32.84			1.17
Southington.....	140.00	15.00			9.00	.04	30.47			1.21
South Windsor.....	66.00	2.72	6.66	6.43	10.00		20.93			22.70
Suffield.....	129.00	29.00	2.30	75.00			106.30			
West Hartford.....	65.00	27.99	4.29				35.35			
Wethersfield.....	50.00	19.00	4.17	.19		3.07	23.38			12.00
Windsor.....	76.00	10.00	.85	24.00		.13	37.91			17.00
Windsor Locks.....	30.00	4.82	.63	5.00		2.93	10.45			3.00
Total.....	2,161.00	296.83	39.42	217.24	91.00	.24	653.58	30.24	1 — 91.11	471.55
Litchfield:										
Barkhamsted.....	85.00			10.00	3.00		10.00			7.92
Bethlehem.....	53.00	4.23		.75			7.98			3.49
Bridgewater.....	60.00			4.01			4.01			1.60
Canaan.....	66.00			7.57			7.57			7.00
Colebrook.....	65.00			8.03			8.03			
Cornwall.....	105.00	.60		.20			.80			11.97
Goshen.....	93.00	5.25		.27			5.52			6.57
Harwinton.....	80.00	.65		4.58			5.23			3.53
Kent.....	115.00			3.50			3.50			1.78
Litchfield.....	158.00	10.76		3.22			13.98			45.73
Morris.....	40.00	2.30		1.58			3.88			4.39
New Hartford.....	110.00	6.00		3.63			9.63			20.25
New Milford.....	285.00	13.00		3.87	20.00		36.87			152.14
Norfolk.....	35.00	4.92		5.65			10.57			7.15
North Canaan.....	45.00	8.00		6.18			14.18			
Plymouth.....	100.00	4.21		.83	6.00		11.79			1.79
Roxbury.....	90.00	3.50				.75	3.50			3.72
Salisbury.....	96.00	90	.81	8.22	15.00		25.01			3.59
Sharon.....	140.00	2.22		3.29	10.00	.08	15.51			1.77
Thomaston.....	55.00	5.41		8.46	10.00		23.87			1.21
Torrington.....	177.00	10.00		33.53			48.53			116.27
Warren.....	180.00				10.00		10.00			28.47
Washington.....	78.00	6.10		1.50			7.60			1.00
Watertown.....	105.00	2.26		4.74		.06	7.06			1.30
Winchester.....	120.00	10.00	.33	7.00	5.00		22.33			35.00
Woodbury.....	90.00	.74		5.19			5.93			7.15
Total.....	2,626.00	101.05	1.14	135.80	84.00	.06	322.88	12.29	51.09	475.83

¹ The mileage of surfaced roads reported for Hartford County for 1909 exceeded the mileage reported for 1914 by 91.11 miles; and for New Haven County by 71.18 miles.

CONNECTICUT—Continued.

TABLE 21.—Miles of public roads outside of incorporated cities, 1914—Continued.

County and town.	Total mileage, all roads.	Surfaced roads.							Graded and drained earth roads.
		Macadam.		Gravel.	Sand-clay.	Brick, paved.	Concrete.	Total surfaced.	
		Plain.	Bitumi- nous.						
Middlesex:									
Chatham.....	108.00	3.03		1.07	3.00			7.10	3.21
Chester.....	40.00	4.58			20.00			24.58	2.19
Clinton.....	35.00	5.32					0.31	5.63	4.18
Cromwell.....	75.00	7.00	1.22	4.00				12.22	
Durham.....	75.00	9.58						9.58	
East Haddam.....	200.00	6.26			20.00			26.26	.01
Essex.....	35.00	20.00	1.43	2.27				23.70	3.00
Haddam.....	115.00	1.07		9.26				10.33	2.89
Killingworth.....	140.00								
Middlefield.....	33.00	11.04		1.50				12.54	
Middletown.....	175.00	21.31	1.21	22.21	30.00		1.03	75.76	15.01
Old Saybrook.....	45.00	11.24		2.18	20.00			33.42	2.10
Portland.....	90.00	10.50	2.38	.29				13.17	37.98
Saybrook.....	30.00	3.45	1.10		5.00			9.55	.12
Westbrook.....	30.00	3.70		3.68				7.38	1.99
Total.....	1,186.00	118.08	7.34	46.46	98.00		1.34	271.22	141.68
New Haven:									
Beacon Falls.....	20.00			4.00				4.00	16.00
Bethany.....	75.00			3.29				28.29	.47
Branford.....	100.00	6.00	2.45		25.00		1.29	9.74	74.34
Cheshire.....	110.00	.75		5.50				.75	53.17
East Haven.....	50.00	4.06	.40	2.00	5.00		.39	11.85	.09
Guilford.....	125.00	2.14		2.69			0.10	4.93	1.88
Hamden.....	42.00	11.00	.27				.61	11.88	11.02
Madison.....	100.00		1.67	7.37				9.04	5.91
Meriden.....	95.00	9.00	3.06	21			1.18	13.45	30.54
Middlebury.....	60.00	2.00		5.45	9.75			17.20	4.47
Milford.....	85.00	4.10	.62	5.67			3.39	13.78	1.51
North Branford.....	60.00	10.00		5.00	10.00			25.00	10.00
North Haven.....	80.00	21.91					.02	21.93	
Orange.....	150.00	10.80	.59	2.19				13.58	25.00
Oxford.....	88.00			6.01				6.01	.33

[illegible]

¹ The mileage of surfaced roads reported for Hartford County for 1909 exceeded the mileage reported for 1914 by 91.11 miles; and for New Haven County by 71.18 miles.

CONNECTICUT—Continued.

TABLE 21.—Miles of public roads outside of incorporated cities, 1914—Continued.

County and town.	Total mileage, all roads.	Surfaced roads.								Graded and drained earth roads.	
		Macadam.		Gravel.	Sand-clay.	Brick, paved.	Concrete.	Total surfaced.	Percentage of total surfaced.		Increase in surfaced mileage over 1909.
		Plain.	Bituminous.								
Windham:											
Ashford.....	105.00	.....		0.09	15.00			15.09			2.99
Brooklyn.....	62.00	7.76		15.00				22.76			3.17
Canterbury.....	100.00	2.00		1.17				3.17			1.44
Chaplin.....	72.00			9.00				9.00			27.00
Eastford.....	70.00			3.37				3.37			2.68
Hampton.....	65.00	.35		.44				.79			3.27
Killingly.....	150.00	17.03		26.49	12.00			55.52			18.91
Plainfield.....	94.00	16.94		6.84	25.00			48.78			2.60
Pomfret.....	100.00	10.00	2.12	11.50				23.62			25.14
Putnam.....	70.00	21.00	1.19	4.68				26.87			3.10
Scotland.....	42.00	.87		2.49				3.36			18.37
Sterling.....	60.00	1.05		7.00				8.05			2.60
Thompson.....	100.00	1.37	3.17	5.79	70.00		0.69	81.02			40.49
Windham.....	95.00	2.00		17.00			.64	19.64			2.49
Woodstock.....	155.00	8.28		13.29	70.00			91.57			
Total.....	1,341.00	88.65	6.48	124.15	192.00		1.33	412.61	30.76	117.62	148.48
Grand total for State.....	14,060.82	923.42	128.28	1,057.93	840.27	1.33	24.22	2,975.45	21.16	321.18	2,219.23

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UNITED STATES DEPARTMENT OF AGRICULTURE



BULLETIN No. 389

Contribution from the Office of Public Roads and Rural Engineering, LOGAN WALLER PAGE, Director



Washington, D. C.



May 10, 1917

PUBLIC ROAD MILEAGE AND REVENUES IN THE CENTRAL, MOUNTAIN, AND PACIFIC STATES, 1914.

A Compilation Showing Mileage of Improved and Unimproved Roads; Sources and Amounts of Road Revenues; Bonds Issued and Outstanding; a Description of the Systems of Road Administration, Fiscal Management, and Other Factors Affecting Road Improvement in Each State.

Prepared jointly by the Division of Road Economics of the Office of Public Roads and Rural Engineering, and State Collaborators.

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INTRODUCTORY.

In 1904 the policy of conducting an investigation at five-year intervals to ascertain the mileage of improved and unimproved roads, the revenues for road purposes, and other related data was adopted. A bulletin embodying data for the calendar year 1904 was published.¹ A similar investigation was conducted for the calendar year 1909 and the data issued as Bulletin No. 41. The investigation made for the calendar year 1914, which forms the basis for this bulletin, differed somewhat from the preceding investigations, as a greater number of State highway departments were in operation and more adequate facilities were possessed by them. Wherever it was practicable to do so, information was obtained directly by collaborators designated by the State highway departments and acting under specific instructions from this office.

In many instances it was impossible for the collaborators to obtain replies from all local officials, and accordingly letters and forms were sent directly from this office to such local officials. In the course of the investigation it was found necessary to enlist

¹ U. S. Dept. Agr., Office of Public Roads Bul. No. 32.

NOTE.—This bulletin will be of interest to officials engaged in the building and maintenance of roads.

the aid of local and State road associations, chambers of commerce, automobile clubs, postmasters, and private individuals in order to obtain adequate information. On account of the absence of detailed records in many of the towns and counties extreme accuracy is impossible. The data on mileage and revenues should therefore be considered as approximate only. Because of the large amount of correspondence necessary to conduct the investigation, considerable delay in the issuance of the data has been unavoidable.

Bulletins already have been issued for the Middle Atlantic States, the New England States, and the Southern States, respectively. These, together with this bulletin, which contains data for the Central, Mountain, and Pacific States, form a complete series embracing all of the 48 States. A convenient reference summary of all of the States also is issued coincident with this bulletin.

ROAD ADMINISTRATION IN THE CENTRAL, MOUNTAIN, AND PACIFIC STATES.

The greater part of all road and bridge work in the States comprised in this group is done under the supervision of county, township, or district authorities. There is, however, an increasing tendency toward State participation and management. Laws have been enacted creating or designating State highway departments or commissions in the States of California, Colorado, Idaho, Illinois, Iowa, Michigan, Minnesota, Missouri, Montana, New Mexico, North Dakota, Ohio, Oregon, South Dakota, Utah, Washington, and Wisconsin. Duties somewhat similar to those exercised by State highway departments or commissions are imposed upon the State engineer in the States of Kansas, Nebraska, Nevada, and Wyoming; and all the functions of a State highway department or commission are exercised by the State engineer and the State board of control in the State of Arizona. An outline of the system of road administration in force in each State is given under the respective State headings.

PUBLIC ROAD REVENUES.

The total revenue applied to roads and bridges in the Central, Mountain, and Pacific States in the year 1914 amounted to \$131,446,647.62, including State appropriations, motor-vehicle registration and license fees, amounts derived from local taxation, and expenditures from bond issues, both State and local. In 1904 the total revenue applied to this purpose amounted to \$36,794,586.67. The increase in 1914 as compared with 1904 was, therefore, \$94,652,060.95, or 257.24 per cent. Table 1 presents in condensed form the information assembled concerning revenues for this group of States for the year 1914, with comparative information for the year 1904.

TABLE 1.—*Revenue applied to roads and bridges.*

State.	Total revenue applied to roads and bridges.		Increase in revenue over 1904.	
	1904	1914	Total increase.	Percentage of increase.
Arizona.....	\$109,309.43	\$982,721.22	\$873,411.79	799
California.....	2,157,396.36	19,171,984.66	17,014,588.30	786.6
Colorado.....	707,223.63	1,937,546.23	1,230,322.60	173.96
Idaho.....	311,588.00	1,371,468.59	1,059,880.59	340
Illinois.....	4,210,950.32	8,734,712.77	4,523,762.45	107.42
Indiana.....	4,335,108.00	14,233,985.93	9,898,877.93	228.34
Iowa.....	3,106,607.50	10,187,507.32	7,080,899.82	227.92
Kansas.....	1,232,817.45	5,544,048.00	4,311,230.55	349.7
Michigan.....	3,179,787.88	9,261,998.00	6,082,210.12	191.27
Minnesota.....	1,961,629.24	6,458,940.07	4,497,310.83	229.26
Missouri.....	2,368,972.79	5,513,048.71	3,144,075.92	132.72
Montana.....	404,097.81	2,888,400.61	2,484,302.80	614.77
Nebraska.....	878,547.40	1,796,277.69	917,730.29	104.4

TABLE 1.—Revenue applied to roads and bridges—Continued.

State.	Total revenue applied to roads and bridges.		Increase in revenue over 1904.	
	1904	1914	Total increase.	Percent- age of increase.
Nevada.....	\$46,875.85	¹ \$245,013.65	\$198,137.80	422.68
New Mexico.....	165,651.56	556,398.82	390,747.26	235.88
North Dakota.....	550,340.72	2,402,383.52	1,852,042.80	436.52
Ohio.....	5,706,083.61	14,334,245.98	8,628,162.37	151.23
Oregon.....	796,375.97	5,310,466.76	4,514,090.79	566.84
South Dakota.....	383,283.07	1,217,809.42	834,526.35	217.73
Utah.....	218,675.73	803,070.63	584,394.85	267.24
Washington.....	1,436,070.19	7,944,717.38	6,508,647.19	453.22
Wisconsin.....	2,181,262.38	9,880,240.50	7,698,978.12	352.26
Wyoming.....	345,931.73	669,661.16	323,729.43	93.58
Total.....	36,794,586.67	131,446,647.62	94,652,060.95	257.24

¹ For 1915.

A comparison showing the average revenues for roads and bridges in the Central, Mountain, and Pacific States per mile of road, per square mile of area, per thousand of rural population, and per \$100 of assessed valuation for the years 1904 and 1914 is presented in Table 2. This average does not indicate, however, the proportion of expenditures for construction and maintenance, respectively.

TABLE 2.—Revenue according to mileage, area, population, and valuation.

State.	Road revenues.							
	Per mile of road.		Per square mile of area.		Per capita.		Per \$100 of assessed valuation.	
	1904	1914	1904	1914	1904 ¹	1914 ²	1904 ³	1914 ⁴
Arizona.....	\$18.25	\$81.38	\$0.96	\$8.63	\$0.89	\$4.81	\$0.27	\$0.70
California.....	46.24	314.09	13.82	123.17	1.45	8.06	.17	.66
Colorado.....	23.40	48.70	6.82	18.69	1.31	2.42	.20	.46
Idaho.....	17.15	56.22	3.73	16.45	1.92	4.21	.51	.82
Illinois.....	44.73	91.32	75.19	155.85	.87	1.54	.41	.37
Indiana.....	63.46	194.06	120.80	394.89	1.72	5.27	.31	.75
Iowa.....	30.32	97.88	55.89	183.27	1.39	4.58	.54	1.13
Kansas.....	12.18	49.92	15.07	67.79	.83	3.28	.34	.20
Michigan.....	45.88	124.84	55.32	161.13	1.31	3.29	.22	.40
Minnesota.....	24.72	69.06	24.26	79.88	1.12	3.11	.26	.44
Missouri.....	21.90	57.40	34.47	80.22	.76	1.67	.19	.30
Montana.....	18.02	73.67	2.76	19.75	1.66	7.68	.22	.83
Nebraska.....	11.05	22.37	11.43	23.38	.82	1.51	.49	.39
Nevada.....	3.72	20.11	.42	2.23	1.10	2.99	.16	.24
New Mexico.....	10.80	46.86	1.35	4.54	.84	1.69	.43	.77
North Dakota.....	9.28	34.92	7.84	34.23	1.72	4.16	.41	.68
Ohio.....	82.17	165.99	140.06	351.84	1.37	3.00	.29	.22
Oregon.....	23.24	144.23	8.33	55.54	1.92	7.89	.54	.59
South Dakota.....	6.46	12.64	4.98	15.84	.95	2.08	.20	.34
Utah.....	30.84	91.15	2.66	9.77	.79	2.15	.18	.40
Washington.....	44.88	187.25	21.48	118.87	2.77	6.95	.55	.79
Wisconsin.....	34.30	130.50	39.47	178.81	1.05	4.23	.14	.40
Wyoming.....	9.45	45.25	3.54	6.86	1.04	4.59	.79	.37
Weighted average.....	30.94	96.74	19.03	67.98	1.21	3.58	.27	.44

¹ Based on the 1900 United States census.² Based on the 1902 United States census.³ Based on the 1910 United States census.⁴ Based on the 1912 United States census.

ROAD AND BRIDGE BONDS.

The total State, county, township, and district road and bridge bonds outstanding on January 1, 1915, in the Central, Pacific, and Mountain States, amounted to \$128,767,414.57. In 1914 the expenditures from bond issues amounted to \$28,949,759.48; bonds were retired to the amount of \$9,214,166.62; bonds voted \$24,960,869.20; and bonds sold \$25,611,229.42.

State bonds have been issued in California, Idaho, Utah, and Washington. In California the bond issue for the construction of a system of State highways amounted to \$18,000,000. Some district road bonds have been issued in Kansas, but it was impossible to ascertain the amounts. No State, county, or township road and bridge bonds were reported for Nebraska, North Dakota, South Dakota, or Wyoming. All of the other States in this group, however, have outstanding local bonds.

Information in regard to bond issues is presented by States in Table 3, and detailed information, showing bond issues by counties, is given under the State headings.

TABLE 3.—*Road and bridge bonds.*

State.	Total outstanding Jan. 1, 1915.	Expended from bond issues during 1914.	Retired during 1914.	Voted during 1914.	Sold during 1914.
Arizona.....	\$295,000.00	\$8,780.59	(1)	\$275,000.00	\$275,000.00
California.....	² 32,277,000.00	8,886,192.56	\$271,000.00	2,712,000.00	2,712,000.00
Colorado.....	90,500.00	1,234.50	(1)	(1)	(1)
Idaho.....	³ 1,339,000.00	226,000.00	(1)	425,000.00	375,000.00
Illinois.....	798,761.55	208,855.41	161,914.34	3,656,500.00	199,350.00
Indiana.....	42,095,357.34	9,396,186.98	5,957,266.47	4,538,221.31	8,619,005.53
Iowa.....	1,960,780.00	(1)	(1)	376,828.00	376,828.00
Kansas.....	(1)	(1)	(1)	(1)	(1)
Michigan.....	10,389,029.43	1,524,557.49	-----	2,080,742.43	2,080,742.43
Minnesota.....	1,411,889.00	429,800.00	49,842.00	62,000.00	358,000.00
Missouri.....	522,500.00	55,000.00	37,500.00	75,000.00	75,000.00
Montana.....	2,224,050.72	102,475.00	33,000.00	462,000.00	440,000.00
Nebraska.....	(1)	(1)	(1)	(1)	(1)
Nevada.....	38,000.00	³ 17,256.79	3,000.00	25,000.00	25,000.00
New Mexico.....	157,000.00	30,000.00	(1)	50,000.00	50,000.00
North Dakota.....	(1)	(1)	(1)	(1)	(1)
Ohio.....	31,175,968.53	6,384,355.74	2,684,593.81	8,702,303.46	8,593,303.46
Oregon.....	1,615,000.00	1,122,817.65	(1)	1,365,000.00	1,365,000.00
South Dakota.....	(1)	(1)	(1)	(1)	(1)
Utah.....	² 541,500.00	6,899.27	(1)	10,500.00	10,500.00
Washington.....	² 1,555,000.00	509,146.50	(1)	133,274.00	35,000.00
Wisconsin.....	281,078.00	40,201.00	16,050.00	21,500.00	21,500.00
Wyoming.....	(1)	(1)	(1)	(1)	(1)
Total.....	128,767,414.57	28,949,759.48	9,214,166.62	24,960,869.20	25,611,229.42

¹ None reported.² Including State bonds.³ Expended in early part of 1915.

The total road mileage in the Central, Mountain, and Pacific States as of January 1, 1915, exclusive of streets in incorporated cities and towns, was 1,358,706, of which 134,141.74 miles, or 9.87 per cent were surfaced. The total road mileage and the mileage surfaced to the close of 1914, and percentage of surfaced roads for 1909 and 1914 are shown for this group of States in Table 4. Detailed information on this subject is presented by counties under the State headings. The percentage of roads surfaced for the years 1904, 1909, and 1914 for these States is shown in figure 1.

TABLE 4.—Road mileage.

State.	Total road mileage, end of 1914.	Surfaced road mileage, end of 1914.	Percentage surfaced.	
			1909.	1914.
Arizona.....	12,075	253.43	4.56	¹ 2.09
California.....	61,039	10,279.73	17.87	¹ 16.84
Colorado.....	39,780	1,193.87	1.08	3
Idaho.....	24,396	679	2.77	2.78
Illinois.....	95,647	11,606.31	9.47	12.02
Indiana.....	73,347	30,962.4	36.7	42.2
Iowa.....	104,074	614.57	2.45	0.59
Kansas.....	111,052	1,148.85	0.38	1.03
Michigan.....	74,190	7,828.51	10.01	10.55
Minnesota.....	93,517	3,967.83	6.83	¹ 4.24
Missouri.....	96,041	6,712.57	4.4	6.98
Montana.....	39,204	609.25	0.41	1.55
Nebraska.....	80,272	1,204.54	0.31	1.5
Nevada.....	12,182	262	0.36	2.14
New Mexico.....	11,873	261.5	0.61	2.2
North Dakota.....	63,796	955	0.23	1.38
Ohio.....	86,354	30,569.17	27.13	35.16
Oregon.....	36,819	4,726.4	9.49	12.83
South Dakota.....	96,306	363	0.5	0.37
Utah.....	8,810	1,153.75	12.23	13.09
Washington.....	42,428	4,922.09	13.19	¹ 11.61
Wisconsin.....	75,707	13,399.47	16.64	17.6
Wyoming.....	14,797	468.5	3.94	¹ 3.16
Total average.....	1,358,706	134,141.74	8.91	9.87

¹ Decrease in surfaced mileage reported does not mean retrogression, but is accounted for by higher standard requirements and greater accuracy of reports in 1914 as compared with previous reports.

The relation of total mileage and surfaced mileage to area and rural population in Central, Pacific, and Mountain States, for the years 1904, 1909, and 1914, is presented in Table 5.

TABLE 5.—Relation of total mileage and surfaced mileage to area and rural population.

State.	Total mileage.				Surfaced mileage.			
	Per square mile of area.		Per 1,000 of rural population.		Per square mile of area.		Per 1,000 of rural population.	
	1904	1914	1904	1914	1904	1914	1904	1914
Arizona.....	0.05	0.11	58.1	85.5	0.002	0.002	2.10	1.79
California.....	.29	.39	65.9	67.2	.056	.066	12.45	11.32
Colorado.....	.30	.38	108.3	100.9	.062	.011	.64	3.02
Idaho.....	.20	.29	119.6	95.4	.002	.008	1.39	2.65
Illinois.....	1.6	1.71	42.6	44.2	.141	.207	3.59	5.37
Indiana.....	1.9	2.03	41.3	47.1	.662	.858	14.44	19.88
Iowa.....	1.84	1.87	61.7	67.3	.029	.001	1	.39
Kansas.....	1.2	1.35	88.8	92.7	.003	.014	.24	.96
Michigan.....	1.2	1.29	47.2	50	.122	.136	4.78	5.28
Minnesota.....	1	1.15	68.7	76.3	.077	.036	5.42	2.42
Missouri.....	1.5	1.39	54.6	50.6	.039	.097	1.38	3.54
Montana.....	.15	.27	141.2	161.5	.0004	.004	.41	2.51
Nebraska.....	1	1.04	97.6	91	.0003	.001	.03	1.36
Nevada.....	.11	.11	358.1	177.8	.0006	.002	1.82	3.82
New Mexico.....	.12	.09	91.3	42.3	.0002	.002	.01	.93
North Dakota.....	.84	.98	200.6	133.8	.003	.013	.71	1.86
Ohio.....	1.79	2.12	32.1	41	.575	.750	10.86	14.54
Oregon.....	.36	.38	122.2	100.6	.027	.049	9.23	12.89
South Dakota.....	.7	1.25	164.4	189.8	.002	.004	.42	.72
Utah.....	.08	.11	41.3	43.9	.007	.014	3.55	5.76
Washington.....	.48	.63	104.3	79	.029	.073	6.44	9.17
Wisconsin.....	1.17	1.37	49.7	56.9	.192	.242	8.31	10.08
Wyoming.....	.1	.15	158.5	144.8	.0015	.005	2.32	4.56
Total average.....	.61	.70	63.9	68.2	.051	.069	5.33	6.74

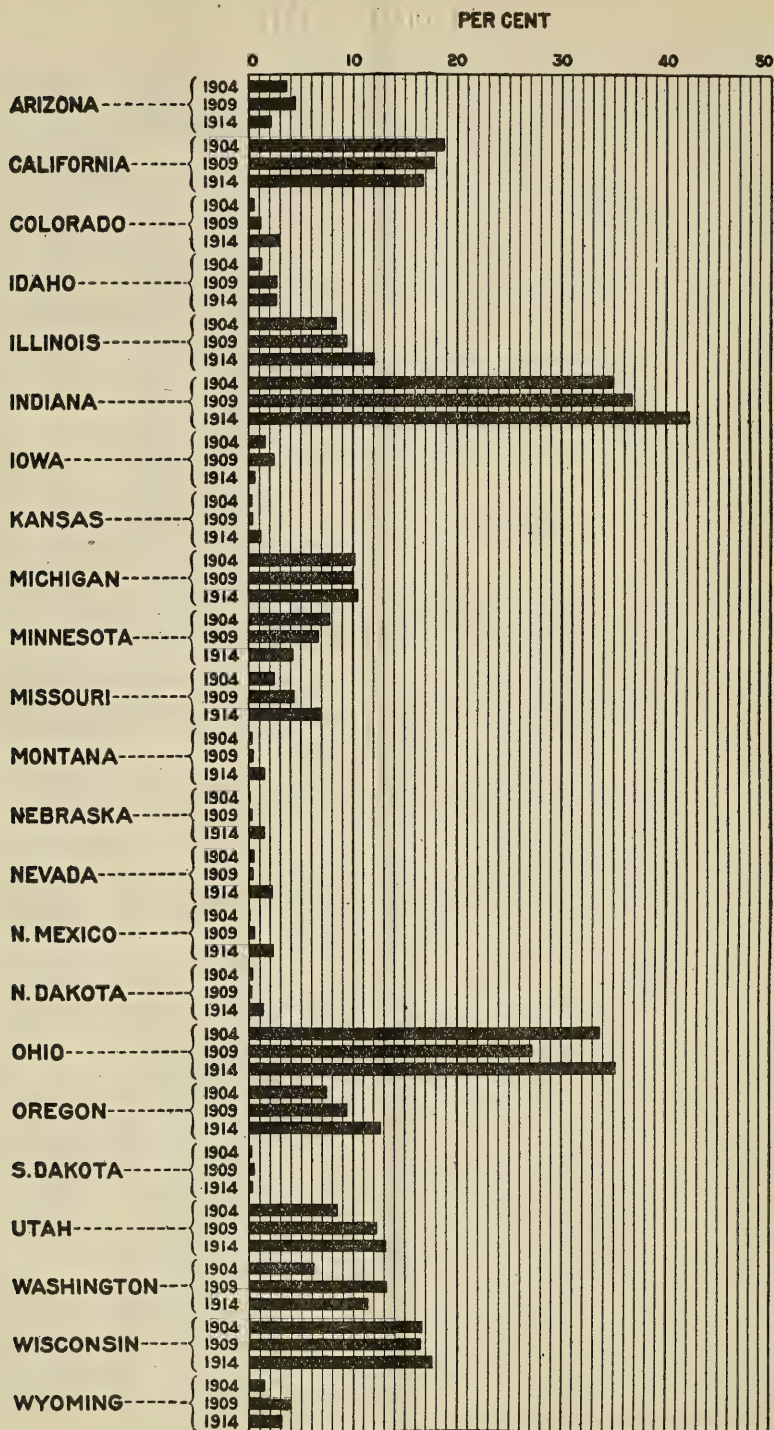


FIG. 1.—Percentage of surfaced roads in the respective States.

Of the 134,141.74 miles of surfaced roads, at the close of 1914, in the Central, Pacific, and Mountain States, 78,825.34 miles, or 58.77 per cent, were of gravel; 31,882.24 miles, or 23.77 per cent, macadam; 13,192.02 miles, or 9.84 per cent, sand-clay; 2,949.64 miles, or 2.20 per cent, bituminous macadam; 1,789.20 miles, or 1.33 per cent, concrete; 794.82 miles, or 0.59 per cent, brick; and 4,708.47 miles, or 3.5 per cent, surfaced with other materials. The distribution of types of surfaced roads as of January 1, 1915, is shown by States in Table 6.¹

TABLE 6.—*Distribution of types of surfaced road, 1914.*

State.	Type.							Total.
	Macadam.	Bitumi- nous mac- adam.	Gravel.	Sand- clay.	Brick.	Concrete.	Miscella- neous.	
Arizona.....	11.23	13.5	125.7	45			58	253.43
California.....	837.4	877.9	3,563.59	582.25		929.19	a 3,489.4	10,279.73
Colorado.....	3		574.25	450.12		2.25	164.25	1,193.87
Idaho.....	42.5	12	168	449		4.5	3	679
Illinois.....	1,675.11	121.53	7,052.3	2,467.95	82.92	148.8	57.7	11,606.31
Indiana.....	10,291.29	168.35	20,264.59	150.25	34.75	53.17		30,962.4
Iowa.....	171.3		413	23		5.77	1.5	614.57
Kansas.....	194.3		151.85	758.5	4.1	1.35	38.75	1,148.85
Michigan.....	1,021.19	94.5	5,230.25	1,375.27		107.3		7,828.51
Minnesota.....	120.25	19	2,825.25	985.33	.5	17.5		3,967.83
Missouri.....	1,531.05	59	3,671.5	1,442.25	1	2.77	5	6,712.57
Montana.....	78		514.25	14			3	609.25
Nebraska.....	39.21	1.3	21	1,131.1	2.4	7.53	2	1,204.54
Nevada.....	2		193	67				262
New Mexico.....		5	184	72.5				261.5
North Dakota.....			955					955
Ohio.....	12,903.87	1,066.29	15,385.93	211	640.41	315.67	46	30,569.17
Oregon.....	1,000.72	137.25	3,060.15	300		28.41	199.87	4,726.4
South Dakota.....		10	212	129			12	363
Utah.....	49	15.5	685.75	401		2.5		1,153.75
Washington.....	502.82	165.52	3,924.48	83.50	26.35	79.42	140	4,922.09
Wisconsin.....	1,408	183	9,597	2,054	2.4	83.07	72	13,399.47
Wyoming.....			52.5				416	468.5
Total.....	31,882.24	2,949.64	78,825.34	13,192.02	794.82	1,789.20	4,708.47	134,141.74
Per cent.....	23.77	2.2	58.77	9.84	.59	1.33	3.5	100

a Oiled earth.

Detailed information regarding sources and amounts of revenues, bonds issued and outstanding, total mileage of roads, and mileage surfaced, systems of administration, and other factors affecting road improvement, is presented under the respective State headings.

ARIZONA.²

Arizona has a land area of 113,810 square miles, a total road mileage of 12,075, of which 253.43 miles, or 2.09 per cent, were surfaced at the close of 1914.

The State engineer is appointed by the governor, by and with the consent of the senate. He is required to be a practical and competent civil engineer, and serves for a term of two years. His duties are to aid the State board of control and the boards of supervisors of the several counties in the selection and designation of State highways and bridges, which are defined to be all highways and parts of highways and bridges heretofore constructed by the Territory or State of Arizona or that may be built hereafter by the State. The boards of supervisors are required to act with the State engineer in the selection of the highways and bridges to be constructed

¹ The tables referred to hereafter in the text will be found in the appendices: Those referring to road mileage are grouped in Appendix A, those referring to revenues expended in Appendix B, and those referring to bond issues in Appendix C.

² In collecting the information for Arizona assistance was rendered by Lamar Cobb, State engineer, and collaborator of the U. S. Department of Agriculture.

in their respective counties, and the State engineer, on request of the State board of control or the board of supervisors of any county, is required to map, plat, and furnish estimates of the cost of construction of any such highway.

All improved State highways and bridges are maintained at the expense of the county wherein located out of the State road tax fund apportioned to such county, under the joint direction of the State engineer and the board of supervisors. An annual State tax of \$250,000 is levied for the State road tax fund. Twenty-five per cent of this fund is expended wholly in the discretion of the State board of control and 75 per cent is apportioned among the several counties in proportion to the amount collected in each and expended by the board of supervisors and the State engineer. The proceeds from the registration and licensing of motor vehicles also are applied to the State road tax fund.

Jurisdiction over roads and bridges in the several counties is vested in the respective boards of supervisors. Each board is authorized to appoint a county engineer, who must be a competent civil engineer and road builder, and serves during the pleasure of the board. The county engineer, under the direction of the board of supervisors, has charge of all highway and bridge work and other engineering construction work undertaken by the county and is required to make all surveys, maps, plans, and specifications required therefor. He may, with the approval of the board of supervisors, appoint necessary assistants.

Special road districts, not exceeding 10 miles in length and 1 mile in width, may be formed upon petition of 25 taxpayers therein to the board of supervisors. The board is required to call an election thereon and a two-thirds vote is necessary to authorize the establishment of such a district. When a special road district is formed a board of three trustees is required to be elected for three years with exclusive charge and control of road work undertaken by the district and of the management and expenditure of its road funds. The district trustees must, on or before July 1 each year, certify to the board of supervisors the amount of money required for road purposes for the ensuing year, and the board of supervisors must levy a land tax in the district sufficient to produce such amount, provided the tax so levied shall not exceed 75 cents on each \$100. If the trustees deem it advisable to spend a larger sum than can be made available within the above limitation, for a period not exceeding five years, they must call a special election thereon, and if two-thirds of those voting favor such larger amount the board of supervisors must levy annually for such period upon all taxable lands in the district such a tax as will produce the amount voted; or, in lieu of such additional tax, the trustees may submit the proposition of issuing bonds of the district, which may be done if authorized by a favorable vote of two-thirds of those voting.

The levy and collection of the road taxes within the district shall not exempt the property within such district from the levy and collection of the general county tax by the board of supervisors, provided that the board of supervisors shall appropriate annually to the use of the special road districts such amount as in their judgment is equitable and just, which amount shall in no case be less than 40 per cent nor more than 65 per cent of the amount of road tax levied and collected within said special road district.

The board of county supervisors may levy a property road tax of not to exceed 25 cents on each \$100 of real and personal property in the county. In counties having road-fund warrants outstanding and unpaid, such levy may be not to exceed 60 cents on each \$100 valuation of real and personal property in the county, one-half of the proceeds to be applied to a fund to be known as the "road warrant redemption fund," and the other half to the general road fund of the county.

No person not a citizen or ward of the United States, or who has not declared his intention to become a citizen, shall be employed upon or in connection with any State, county, or municipal work or employment.

Every able-bodied male over 21 and under 60 years of age residing outside incorporated cities and towns, and not exempt by law, is required to pay a road tax of \$2 a year.

Provision is made for the working of State convicts in the construction and maintenance of State highways and bridges under the control and supervision of the board of control and the State engineer. Funds to meet the cost of so working prisoners are provided out of the prison-maintenance fund and the State road-tax fund. Counties receiving the labor of State convicts shall not, during the same fiscal year, be entitled to receive any portion of the State road-tax fund under the board of control, except such as would be a proper engineering charge.

ROAD MILEAGE.

According to the reports received, Arizona had on January 1, 1914, a total of 12,075 miles of public roads, of which 253.43 miles, or 2.09 per cent were surfaced. Of the surfaced roads 11.23 miles were macadam, 13.50 miles were bituminous macadam, 125.7 miles were gravel, 45 miles were sand-clay, 50 miles were cinders, 7 miles were oiled gravel, and 1 mile was oiled caliche or gravel. There were also reported 2,695.96 miles of graded and drained earth roads. The total of all public roads reported for 1909 was 5,987 miles, of which 273 miles, or 4.56 per cent, were surfaced, thus indicating that the total mileage increased considerably, while the surfaced mileage is about the same as that reported for 1909. Detailed information in regard to road mileage in Arizona at the close of 1914 is shown by counties in Table 7.

REVENUES APPLIED TO ROADS AND BRIDGES.

The total revenue applied to roads and bridges in 1914 amounted to \$982,721.22, of which \$523,114.44 was derived from general county road and bridge taxes, \$94,930 from per capita and other taxes, \$8,780.59 from county bond issue funds, and \$355,896.19 from State appropriations, motor vehicle tax, and State road tax. In 1904 Arizona applied \$109,309.43 to road and bridge work. The gain in 1914 over 1904 was \$873,411.79, or 799 per cent. Revenues applied to roads and bridges are shown in Table 30.

ROAD AND BRIDGE BONDS.

The total county road and bridge bonds outstanding on January 1, 1915, amounted to \$295,000. In 1914, \$275,000 road and bridge bonds were voted and sold, and \$5,000 retired. Only \$8,780.59 was expended from bond funds during 1914. The bond transactions are shown in Table 53.

CALIFORNIA.¹

California has a land area of 155,652 square miles, a total road mileage of 61,039, of which 10,279.73 miles, or 16.84 per cent, were surfaced at the close of 1914.

There is a department of engineering, which consists of an advisory board, composed of the governor, as ex officio member and chairman, the State engineer, the general superintendent of State hospitals, the chairman of the State board of harbor commissioners of San Francisco, and three other members. The State engineer and three members are appointed by the governor, and serve during his pleasure. The department of engineering, by and through the chairman of the advisory board, is authorized to appoint a State highway engineer, skilled and experienced in highway construction. The department also is authorized to appoint assistant engineers and other assistants as needed. All State highway work is under the direction and supervision of the department of engineering, which is charged by the legislature with the duty of acquiring, constructing, and maintaining a system of State highways, for which an issue of \$18,000,000 of State bonds has been authorized. This duty is exercised by

¹ In collecting the information for California assistance was rendered by A. B. Fletcher, State highway engineer, and collaborator of the U. S. Department of Agriculture.

this department through its three appointed members, who are designated as the California Highway Commission. The State highway engineer, subject to the direction of the commission, has immediate charge of constructing the system of State highways. A statute also exists authorizing the State to aid counties to the extent of paying one-third of the cost of certain roads, but the legislature has failed to appropriate the funds necessary to make this statute operative.

General jurisdiction and control of county roads and bridges vests in boards of supervisors. These boards divide their respective counties into road districts, and each supervisor is ex officio road commissioner in his supervisor district, in charge of the highways and bridges under the direction and orders of the board of supervisors.

Boards of supervisors may establish road improvement districts on declaration of intention so to do and hearing thereon. If a majority of the landowners within the proposed district protest in writing against the ordering of the proposed work as an entirety the board can not proceed further for a period of one year. Improvements made in road-improvement districts are paid for by bonds which are redeemed, both interest and principal, from a special fund constituted partly by transfer from the county road funds and partly by levy of special assessment taxes upon all land in the district. A superintendent of work is appointed by the board of supervisors, which also may appoint an engineer, to be designated "engineer of work."

A board of supervisors, on receiving a petition signed by freeholder electors equal in number to 10 per cent of the vote cast for governor in said county at the last election, praying that the matter of issuing bonds of the county for highway purposes be submitted to the electors of the county, may appoint as a highway commission three residents and freeholders especially qualified to have charge of the improvement of highways and to serve for a term of two years. This commission shall investigate immediately the main public highways of the county and their connections and ascertain which should be improved by the issuance of bonds, the kind of improvement that should be made and the probable cost. With the consent of the board of supervisors, the commission may employ a competent engineer and other necessary assistants. The commission then must report to the supervisors the highways proposed to be improved and the amount that should be raised by the issuance of bonds. If the board of supervisors approve and adopt the report, the proposition of issuing bonds shall be submitted to an election. After such roads are improved the board of supervisors may appoint a superintendent or inspector to have charge of the work of maintaining and repairing them.

Boulevard districts may be formed by the board of supervisors of any county when petitioned by not less than 25 freeholders in the proposed district, and after hearing and submitting the proposition to an election. A majority vote is necessary to authorize the formation of such a district. At such election three persons shall be elected to constitute a boulevard commission. Each boulevard district may lay out, establish, construct, acquire, and maintain one or more boulevards. The boulevard commission may call an election on the question of issuing bonds of the district to pay for such improvements. A two-thirds vote of those voting is required to authorize the issue of such bonds. The boulevard commission is required each year to furnish the board of supervisors with an estimate of the amount of money that will be needed the ensuing fiscal year, and the supervisors must levy a tax on the assessed value of the real property of the district sufficient to raise the amount. A boulevard district may be dissolved at any time on a vote of two-thirds of the qualified electors residing therein.

Permanent road divisions may be formed by the board of supervisors on petition signed by a majority of the landowners residing in the proposed division and after hearing thereon. Special taxes may be levied or bonds issued in such divisions, if authorized at an election held thereon, a majority vote of those voting being necessary to authorize the tax and a two-thirds vote in the case of bonds.

The board of supervisors may establish a general road fund and order apportioned thereto an amount not exceeding 35 per cent of the aggregate road taxes collected from all sources. The general road fund is applied in the following manner: First, in the payment of the cost of general county road improvements; second, in assisting weak and impoverished districts; and third, in payment of such demands as are payable by law out of the general road fund.

Boards of supervisors may levy an annual property road tax of not to exceed 40 cents on each \$100 of assessed valuation of the county, and also a road poll tax of \$3 on every male over 21 and under 55 years of age not exempt by law. Thirty-five per cent of the proceeds of each levy goes into the general road fund. Boards of supervisors may levy a special road fund tax of not to exceed 2 mills on each dollar of assessed valuation of the county, outside of incorporated towns or cities, which shall be expended in the several districts in proportion to the amounts collected in each district. In addition, on petition of a majority of the property owners of any road district, a special road tax of not to exceed 2 mills on each dollar of assessed valuation in the district may be levied by the board. One-half of the net receipts from the registration and licensing of motor vehicles is paid to the counties from which collected, to be used for road and bridge purposes, and the other half is used by the department of engineering for the maintenance and improvement of State highways.

Bonds may be issued for road purposes by boards of supervisors, after having submitted the question to a vote of the people and having received a favorable vote of two-thirds of those voting. The bonded indebtedness of a county at no time shall exceed 5 per cent of its taxable property valuation. Whenever any county highway is improved under a county bond issue, which issue covers all property of the county, the board of supervisors shall provide a continuous system for the maintenance of such highways and may levy annually for that purpose a tax of not to exceed 7 cents on each \$100 valuation of the county for each 100 miles of such improved highways therein.

No person not a native-born or naturalized citizen of the United States can be employed in any department of the State, county, or city governments.

Provision is made for utilizing the labor of both State and county convicts in highway work.

ROAD MILEAGE.

According to the reports received, California had at the close of 1914 a total of 61,039 miles of public roads, of which 10,279.73 miles, or 16.84 per cent, were surfaced. Of the surfaced roads 929.19 miles were concrete, 837.4 macadam, 877.9 bituminous macadam, 3,563.59 gravel, 582.25, sand-clay, and 3,489.4 oiled earth. There was also reported 18,389 miles of graded and drained earth roads. In 1909 California reported 48,069 miles of public roads, of which 8,587 miles, or 17.87 per cent, were surfaced, thus indicating a gain in surfaced roads for the five-year period of 1,691.98 miles in spite of the fact that several counties reported a larger mileage of surfaced roads in 1909 than was reported for 1914. This is shown in Table 8.

REVENUES APPLIED TO ROADS AND BRIDGES.

The total revenue applied to roads and bridges in the fiscal year ended June 30, 1915, amounted to \$19,171,984.66, exclusive of San Francisco County, which is coextensive with the city of San Francisco. It was impossible to secure this information for the calendar year 1914. Of this amount, the counties expended from revenues derived from taxation and bond issues, \$9,790,238.42 for highways and \$2,531,148.63 for bridges, and the State expended \$6,850,597.61, of which \$6,488,217.13 was for the construction of State highways and \$362,380.38 was for the construction and maintenance of State roads. The funds used in the construction of State highways was derived from the \$18,000,000 State bond issue. Of the funds used in the construction

and maintenance of State roads \$307,398.71 was derived from automobile license fees and \$54,981.77 from special appropriations by the State legislature. The total revenue applied to roads and bridges in 1904 amounted to \$2,157,396.36, an increase in the 10-year period of \$17,014,588.30, or 786.6 per cent. Detailed information on this subject is presented in Table 31.

ROAD AND BRIDGE BONDS.

The total road and bridge bonds outstanding in the early part of 1915 amounted to \$32,277,000, of which the counties had issued \$14,277,000 and the State \$18,000,000. In 1914 the counties expended from bond funds a total of \$2,397,975.43, and the State expended from State bonds \$6,488,217.13. In the same year there was voted and sold by the counties \$2,712,000, and there was retired \$271,000 road and bridge bonds. The term of State bonds is 50 years, and rate of interest 4 per cent. They are to be paid off in annual installments of \$400,000 after July 1, 1917. Details of county bond issues are presented in Table 54.

COLORADO.¹

Colorado has a land area of 103,658 square miles, a total road mileage of 39,780, of which 1,193.87 miles, or 3 per cent, were surfaced at the close of 1914.

The State highway commissioner is appointed by the governor for a term of four years. The governor also appoints an advisory board of five members, one from each of five districts of the State and one of whom is retired each year. The State highway commissioner and the advisory board appoint a secretary who must be a civil engineer, and other necessary help. It is the duty of the State highway commissioner and his assistants to give such advice, assistance, and supervision regarding road construction, improvement, and maintenance throughout the State as time and conditions may permit. The board of commissioners of each county is required to prepare and forward to the State highway commissioner a map showing all roads of the county and indicating those of sufficient importance to receive State aid. The State highway commissioner is required on or before January 1 of each year to have on file in his office a map showing all the roads in each county, and in color those he deems to be of sufficient importance to receive State aid and which, when completed, will provide an adequate system of State roads. Such roads may be divided into two classes: First, those of primary importance, and, second, those of secondary importance. Unless otherwise directed roads of primary importance shall be improved first. On the 1st day of March each year the State highway commissioner and the advisory board apportion the State road fund among the different counties of the State and notify the board of commissioners of each county of the amount apportioned thereto. In making the apportionment, population, area, amount expended by each county on roads, and the difficulty of road construction in each county are considered. The boards of county commissioners make all surveys, plans, specifications, and estimates for all work on State roads in their respective counties, in accordance with rules and regulations prescribed by the State highway commissioner and the advisory board, and all work on such roads in the several counties is under the county board. The county boards of the respective counties are authorized to employ a county engineer to have charge of all such work under their direction.

Jurisdiction over roads and bridges in the several counties is exercised by the boards of county commissioners, who may divide their counties into suitable road districts and appoint a road overseer for each district. A county road supervisor may be elected by the county board of commissioners of each county, except in counties whose boundaries coincide with the boundaries of a city and counties in which revenues for road purposes are less than \$12,000. The supervisor so elected must be a

¹ In collecting the information for Colorado assistance was rendered by J. E. Maloney, State highway engineer, and collaborator of the U. S. Department of Agriculture.

practical road builder and shall have charge of all matters pertaining to roads in the county, subject to the county board, and shall have power to form road-dragging districts.

Counties may be organized into corporate road districts by the boards of county commissioners on petition signed by a majority of the qualified voters of the county. In counties so organized into road districts, the office of road overseer is abolished, and the county commissioners appoint a superintendent of roads and bridges. There is elected in each such road district a board of directors, consisting of three members, to have complete control of all public roads and bridges within the district, except as limited by law. A special property road tax is levied by the board of county commissioners in such district in such amount as requested in writing by the board of directors, but not to exceed 50 cents on each \$100 of taxable valuation. Also, all able-bodied men over 21 and under 50 years of age in each such district are required to pay an annual road tax of \$3 or work two days on the public roads.

Public improvement districts may be formed in a county when authorized by a special election of property owners called for that purpose by the county board of commissioners. A majority vote of those voting at such election is necessary to authorize the formation of such districts. Such districts may issue bonds, but the amount to be issued must have been specified in the call for the election.

Any city or incorporated town may aid in the construction and repair of any highway leading thereto by appropriating therefor not exceeding 50 per cent of the highway tax belonging to said city or incorporated town. Such aid shall not be extended beyond 2 miles from the corporate limits, and then only on petition to the council or trustees and after having received the favorable vote of a majority of those voting at an election held thereon.

A State levy of one-half mill is made annually upon all taxable property in the State and the proceeds applied to the State road fund. Also, all money accruing to the internal improvement permanent fund and the internal improvement income fund is applied to the State road fund. Fifty per cent of the revenue collected from the registration of motor vehicles is paid to the several counties in proportion to the amounts collected therein, and the other 50 per cent is applied to the State road fund.

The boards of county commissioners may levy a property road tax in their respective counties of not to exceed \$1 on every \$100 of taxable valuation. County boards of commissioners may issue road bonds when authorized by a majority of those voting at an election called thereon, but the amount of such bonds, including the existing indebtedness, shall not exceed \$6 on each \$1,000 in counties where the taxable valuation exceeds \$5,000,000, and \$12 on each \$1,000 in counties where the taxable valuation is less than \$5,000,000 and more than \$1,000,000.

Except in corporate road districts, every able-bodied man between the ages of 21 and 45 years, not exempt by law, is required to pay to the road overseer of his district \$2 or perform two days' work on the public roads of his district.

Provision is made for the working of both State and county convicts on public highways.

ROAD MILEAGE.

At the close of 1914 Colorado had, according to reports received, 39,780 miles of public road, of which 1,193.87, or 3 per cent, were surfaced. Of the surfaced roads 574.25 miles were gravel, 450.12 miles sand-clay, 2.25 miles concrete, 3 miles macadam, and 164.25 miles were surfaced with other materials. There were also reported 12,104.85 miles of graded and drained earth road.

Reports received from the various counties in 1909 indicated that Colorado at that time had 320.5 miles of surfaced road, indicating a gain from 1909 to 1914 of 873.37 miles of surfaced road. Information regarding the road mileage for 1914 is presented in Table 9.

REVENUES APPLIED TO ROADS AND BRIDGES.

The total revenue applied to roads and bridges in 1914 amounted to \$1,937,546.23, of which \$1,553,655.91 was derived from the general county road and bridge tax; \$25,040.36 was received by counties from motor-vehicle licenses; \$56,340.85 was received by counties from the forest-reserve fund; \$285,851.61 was received by counties from the State fund; \$15,423 was appropriated by the State for the administration of the State highway department; and \$1,234.50 was expended from the bond-issue fund in Garfield County. The total revenue applied to roads and bridges in 1904 amounted to \$707,223.63, a gain within the 10-year period of \$1,230,322.60, or 173.96 per cent. Detailed information in regard to revenue applied to roads and bridges is shown by counties in Table 32.

ROAD AND BRIDGE BONDS.

The total road and bridge bonds outstanding on January 1, 1915, amounted to \$90,500, of which \$55,500 was for Garfield County and \$35,000 for San Miguel County. Bonds in both counties bear 6 per cent and the Garfield County bonds run for 20 years. There was expended during the year 1914, \$1,234.50 from the bond-issue funds in Garfield County. No State road and bridge bonds have been issued.

IDAHO.¹

Idaho has a land area of 83,354 square miles, and a total road mileage of 24,396, of which 679 miles, or 2.78 per cent, were surfaced at the close of 1914.

The State highway commission consists of the secretary of state, who is ex officio a member and secretary, and two other members appointed by the governor for terms of three years. The commission appoints a State highway engineer, who is the executive officer of the commission and may be removed by it. The State highway commission, acting through its executive officer, has general powers and jurisdiction over the laying out, constructing, improving, and maintaining of a system of State highways and bridges and the expenditure of State highway funds. The commission is authorized to appoint such assistant engineers and other assistants as may be necessary and also to advise, assist, and cooperate with local road officials in all matters pertaining to highway and bridge construction and maintenance.

A system of State highways, to consist of main trunk lines connecting the larger centers of population, was to be selected by the State highway commission and plans prepared therefor. All highways constructed by the State or by the aid of the State are State highways and shall be maintained at the sole expense of the State. Where highways are built by the State in cooperation with a county or a highway district or a good-road district in any county, the county must pay, if the cooperation is with a county, not less than two-thirds of the cost, and the district must pay, if the cooperation is with a district, not less than one-half the cost, if the taxable valuation of the district is \$1,000,000 and less, and not less than two-thirds of the cost if the taxable valuation of the district is more than \$1,000,000. State bonds are authorized to pay a portion of the cost of constructing the system of State highways. A State highway fund is created for a like purpose.

The board of county commissioners in each county is vested with jurisdiction in all matters pertaining to roads and bridges therein. Boards of county commissioners may divide their respective counties into suitable and convenient road districts and appoint one road overseer for each district. The road overseers are subject to removal by the board of county commissioners. A board of county commissioners may appoint a road supervisor for the county who shall have immediate control of all road and bridge work in the county under the board of county commissioners.

¹ In collecting the information for Idaho assistance was rendered by E. M. Booth, State highway engineer, and collaborator of the U. S. Department of Agriculture.

Highway districts may be formed in any county when petitioned for by 50 or more holders of title or evidence of title to lands wholly within the limits of a single county and aggregating not less than 20,000 acres of contiguous territory and at least one-tenth of the total acreage of the proposed district. An election and a favorable vote of a majority of those voting is necessary before a highway district may be formed. Three highway commissioners shall be elected in each district for terms of four years each. The highway commissioners of each district constitute the highway board and have full power and authority to construct, maintain, repair, and improve all highways within the district. As soon as possible after the organization of the highway district, the highway board appoints a director of highways, skilled by experience in road construction and maintenance, who serves for a term of four years and has immediate control of all highways within the district.

The highway board may levy a property road and bridge tax which shall not exceed 25 cents for roads and 10 cents for bridges on each \$100 taxable property in the district, but the levy for roads shall not, when added to the amount of levy made by the county commissioners for road purposes that year, exceed 40 cents on the \$100. The highway board may, however, by resolution, levy a special property road tax of not to exceed 25 cents on each \$100 of all taxable property in the district outside the limits of any municipality; or, if not on all taxable property of the district, on petition of a majority of the resident taxpayers of any division of the district, such special tax may be levied in an amount not to exceed 25 cents on the \$100 of taxable property in such division, provided that no levy shall be made which, with the amount of any special levy made by the board of county commissioners for that year, will exceed 25 cents on the \$100. Bonds in an amount not to exceed 10 per cent of the assessed valuation may be issued and outstanding at any one time, if authorized by a two-thirds majority at an election thereon; and, if stated in the order of election, part of the taxes necessary to pay the interest and principal of such bonds may be levied on lands abutting the roads improved from the proceeds thereof.

A special good-road district may be created in any county for the purpose of improving any or all of the public roads therein on petition to the county board of commissioners, signed by a majority of all the freeholders residing within the proposed district. After a hearing an election is held to determine if such district shall be formed and to elect three good-road commissioners. A majority vote is required to authorize the formation of such district. The board of good-road commissioners shall have authority, by and with the consent of a two-thirds majority at an election called thereon, to issue bonds for improving the roads of such district, in an amount not to exceed 25 per cent of the assessed value of real property in the district.

From the road taxes collected from all sources, the board of county commissioners may set apart annually not to exceed 25 per cent of the aggregate for general county road purposes.

The board of county commissioners may levy an annual property road tax of not less than 10 nor more than 100 cents on each \$100 of taxable valuation of the county. If the road fund or the bridge fund of the county becomes unreasonably burdened by the expense of constructing, maintaining, or repairing any road or bridge, a special tax may be levied not to exceed one-half of 1 per cent on the taxable property of the county.

The board of county commissioners in any county may levy a special property highway tax of not to exceed 100 cents on each \$100 of assessed property valuation outside the limits of incorporated towns or villages. In the event that said board deems it inadvisable to levy such a tax on the county, the levy may be made by the board in any road district or districts, if petitioned for by a majority of the resident taxpayers thereof, the amount of taxes that may be thus levied to be as set forth in the petition, but not to exceed 100 cents on each \$100. The proceeds of such levy, when made

within a district, shall be expended only within the district, and if a majority of the resident taxpayers so petition may be paid in labor.

The board of county commissioners levies a road poll tax of not to exceed \$4 upon each able-bodied male from 21 to 50 years of age within the county, including those residing in incorporated cities, towns, and villages. Of such taxes collected within any incorporated city, town, or village, 75 per cent shall be paid to such municipality for the benefit of its road fund.

County boards of commissioners may issue bonds for road purposes when authorized by a two-thirds majority vote at an election called thereon.

Authority is granted for the working of both State and county prisoners on the public highways.

ROAD MILEAGE.

At the close of 1914 Idaho had a total of 24,396 miles of public roads, of which 679 miles, or 2.78 per cent, were surfaced. Of the surfaced mileage 42.5 miles were macadam, 168 gravel, 449 sand-clay, 12 bituminous macadam, 4.5 concrete, and 3 miles cinders. There were also reported 4,399 miles of graded and drained earth road. The total of all public roads for the year 1909 amounted to 18,403, of which 510.5 miles, or .77 per cent, were surfaced, showing an increase in surfaced mileage in the five-year period of 168.5 miles. Detailed information regarding road mileage for 1914 is presented by counties in Table 10.

REVENUES APPLIED TO ROADS AND BRIDGES.

The total revenue applied to roads and bridges in 1914 amounted to \$1,371,468.59. Of this amount \$776,600.87 was derived from the regular county road and bridge tax, \$319,055.60 from special taxes and other sources, \$226,000 from county and district road and bridge bond funds, and \$49,812.12 from State appropriations expended under the direction of the State highway department for State-aid roads. Of the latter amount \$21,733.21 was for construction, \$21,713.44 for engineering, and \$6,365.47 for administration. The engineering expenses were incurred in laying out a system of State highways on which future appropriations are to be applied. In 1904 the total revenue applied to roads amounted to \$311,588, showing an increase for the 10-year period of \$1,059,880.59, or 340 per cent. Detailed information showing the revenues applied to roads and bridges during 1914 is presented by counties in Table 33.

ROAD AND BRIDGE BONDS.

The total State, county, and district road and bridge bonds outstanding on January 1, 1915, amounted to \$1,339,000, of which counties and districts issued \$834,000 and the State \$505,000. The State bonds were issued between 1905 and 1913, and bear from 4 to 5 per cent interest. They are all sinking fund bonds with call provisions and terms extending from 5 to 30 years. In 1914 there was expended from local bond funds \$226,000, there was voted \$425,000, and there was sold \$375,000. The terms of the bonds sold during 1914 were from 10 to 20 years and the interest rate varied from 5 to 6 per cent. No State road and bridge bonds were issued in 1914. Detailed information regarding road and bridge bonds is shown by counties in Table 55.

ILLINOIS.¹

Illinois has a land area of 56,043 square miles, a total road mileage of 95,647, of which 11,606.31 miles, or 12.02 per cent were surfaced at the close of 1914.

The governor, by and with the advice and consent of the senate, appoints the State highway commission of three members, who serve six years each. One member

¹ In collecting the information for Illinois assistance was rendered by Wm. M. Marr, State highway engineer, and collaborator of the United States Department of Agriculture.

shall be designated as president of the commission. The governor also appoints a chief State highway engineer and an assistant State highway engineer. The State highway commission has general supervision of highways and bridges constructed, improved, and maintained in whole or in part by aid of State moneys; aids local road officials by giving advice and causing to be prepared plans, specifications, and estimates for highway and bridge work; lets all contracts for the construction or improvement of State-aid roads, and prescribes a uniform system of auditing and accounting for all road and bridge moneys. The chief State highway engineer and the assistant State highway engineer are the administrative and technical agents of the State highway commission. All subordinate appointments in the State highway department are subject to the State civil-service laws.

Public highways, or sections thereof, including bridges, may be laid out, improved, or constructed at the joint expense of the State and any county, the State contributing one-half the expense and the county or counties through which the highway or a portion thereof passes, one-half. The boards of the several counties designate and indicate on a map public highways within their respective counties of sufficient importance to receive State aid; but the total mileage of highways so designated in any county may not exceed 15 per cent of the total road mileage in counties of the first class; 20 per cent in counties of the second class, and 25 per cent in counties of the third class. The board of supervisors or county commissioners, as the case may be, specify the type of improvement to be made, which is final and not subject to change by the State highway commission; but decision as to type shall not be made until the board has secured from the commission detailed estimates of the cost of the several types of road. If earth roads are specified and built, the county pays all maintenance cost; but if gravel or macadam is specified and constructed the State pays one-half of the maintenance cost.

Appropriations made by the general assembly for State aid are apportioned by the State highway commission to the several counties in the ratio that the total amount levied and collected for roads and bridges in each county bears to the total amount so levied in the State for roads and bridges. The amounts so apportioned are duplicated by the counties and used in constructing State-aid roads. If a county desires to improve its State-aid roads more rapidly than can be done with its annual apportionment, it does so by advancing the necessary funds out of any county funds available, or by issuing county bonds. Before bonds are issued, however, an election must be called thereon, and a majority of those voting must favor the proposition. Counties so expediting the improvement of their State-aid roads are entitled thereafter to receive their apportionment of State aid until the State has contributed its portion of the cost thereof. Improvements are initiated by the county boards by passing a resolution requesting State aid. The State highway commission causes necessary surveys, plans, specifications, and estimates to be made.

In each county of the State there is a county superintendent of highways, appointed in the manner following: The county board of each county submits to the State highway commission a list of from three to five persons, residents of the county. The State highway commission, by competitive examination, selects from among the names submitted those best fitted for said office and so certifies to the county board submitting the list, which appoints from the number found eligible one superintendent of highways for a term of six years and subject to removal.

The county superintendent of highways is required, subject to the rules and regulations of the State highway commission, to prepare plans, specifications, and estimates for all bridges to be built by the county, to be approved by the State highway commission before adoption; to act for the county in all road and bridge matters and advise town and district highway commissioners in regard to highway and bridge work; to supervise the repair and maintenance of all State-aid roads within the

county, subject to the direction of the State highway commission; and to perform such other duties as may be prescribed by law, the rules and regulations of the State highway commission, or the direction of the State highway engineer.

The powers of the county as a body corporate and politic, in counties not under township organization, are exercised by the board of county commissioners, and, in counties under township organization, by the board of supervisors, which is composed of the town and such other supervisors as are or may be elected.

For all purposes relating to the construction, repair, maintenance, and supervision of roads and bridges, the several towns in counties under township organization and road districts in counties not under township organization are, as near as may be, regarded as analogous in corporate authority, and the powers and duties of their highway officers are similar in extent and effect. Counties not under township organization are divided into road districts by the county boards. In each township and in each road district there is elected, for terms of three years each, a board of three highway commissioners. These boards have charge of all road and bridge matters in their respective towns and road districts, and are required each year to certify to the county board the taxes necessary to be levied on the property therein for road and bridge purposes; but such tax must not exceed 61 cents on each \$100 of assessed valuation, and one-half of the amount collected in any incorporated city, town, or village improving and maintaining its own streets is paid to such municipality and applied to its road fund.

On petition of not less than 25 legal voters of any township or road district, addressed to the town or district clerk, a special election may be called on the question of having a single highway commissioner in such township or road district. A favorable vote of a majority of those voting is required.

On petition of 25 per cent of the landowners who are legal voters in any township or road district to the town or district clerk an election may be called on the question of levying a tax of not to exceed \$1 on each \$100 of assessed valuation on all property in the town or district for the purpose of constructing and maintaining gravel, macadam, or other hard-surfaced roads, and on petition of the highway commissioners, officially, and of 100 freeholders of any town or district the question of issuing bonds for that purpose may be submitted to an election, a majority vote of those voting being required.

County boards are vested with powers similar to those conferred on boards of highway commissioners with reference to the construction, repair, and maintenance of gravel, macadam, and other hard-surfaced roads in their county, and may assist towns or road districts in the construction of such roads to the extent of 25 per cent of the cost; but the question of a special permanent road tax or of issuing bonds for that purpose must be submitted first to a vote, on petition of 100 landowners who are legal voters of the county.

If the highway commissioners of any township or road district desire to expend on any bridge or approaches thereto a greater sum than is available otherwise, an election may be called and the question of issuing bonds submitted. A favorable vote of a majority of those voting is required.

Not less than \$3 nor more than \$5 per mile of road is appropriated each year from the road and bridge fund of each township or road district to be known as a "road drag fund" and to be used for dragging earth roads.

In each town or road district a road poll tax of from \$1 to \$3, payable in cash, may be imposed on each able-bodied male between 21 and 50 years of age, not exempt by law. One-half of the proceeds of this poll tax collected in any incorporated city, town, or village which improves and maintains its own streets is paid to such municipality and applied to its road fund. The road poll tax, however, may be abolished by a favorable vote of a majority of those voting at an election thereon.

The proceeds from the licensing and registration of motor vehicles is applied to the State road fund.

The constitution limits the amount of indebtedness which may be incurred or outstanding at any one time by any county, township, or other municipal corporation, to not more than 5 per cent of the value of the taxable property therein.

Authorization is given for the working of State convicts in the preparation of road materials and on the public highways.

ROAD MILEAGE.

At the close of 1914 Illinois had 95,647 miles of public road, of which 11,606.31 miles, or 12.02 per cent, were surfaced. Of the surfaced roads, 1,675.11 miles were macadam, 7,052.30 miles gravel, 2,467.95 miles sand-clay, 148.80 miles concrete, 121.53 miles bituminous macadam, 82.92 miles brick, and 57.7 miles surfaced with other material. There were also reported 41,143.31 miles of graded and drained earth road. At the close of 1909 Illinois reported 94,141 miles of public road, of which 8,914 miles, or 9.47 per cent, were surfaced, thus indicating an increase in surfaced road mileage in the 5-year period of 2,692.31 miles. Detailed information in regard to road mileage in 1914 is presented in Table 11.

REVENUES APPLIED TO ROADS AND BRIDGES.

The total revenue applied to roads and bridges in 1914 amounted to \$8,734,712.77, of which \$7,451,353.18 was received from general county and township taxation; \$968,217.18 from State aid, poll tax, special hard-road tax, and other sources; \$208,855.41 from bond-issue funds expended by local authorities, and \$106,287 expended from State appropriation and automobile revenues for administration, engineering, and miscellaneous equipment by the State highway department. Of the latter sum, \$51,735 was expended for administration and engineering and \$54,552 for miscellaneous equipment. The total revenue applied to roads and bridges in 1904 amounted to \$4,210,950.23, showing an increase in revenue applied to roads and bridges for the 10-year period of \$4,523,762.54, or 107.42 per cent. Detailed information showing the receipts from taxation is presented by counties in Table 34.

ROAD AND BRIDGE BONDS.

According to reports received, the total bonds outstanding on January 1, 1915, amounted to \$798,761.55; these were issued principally by townships. In 1914 there were voted \$3,656,500 road and bridge bonds, which included \$2,000,000 for Cook County and \$1,500,000 for Vermilion County, which latter were not sold on account of a suit against the county. In 1914 there were sold \$199,350 road and bridge bonds and \$161,914.34 were retired. Bond-issue funds expended in 1914 amounted to \$208,855.41. Detailed information in regard to bond issues is presented by counties and townships in Table 56.

INDIANA.¹

Indiana has a land area of 36,045 square miles, a total road mileage of 73,347, of which 30,962.4 miles, or 42.2 per cent, were surfaced at the close of 1914.

In every county maintaining free gravel or macadam roads the board of county commissioners appoints a county highway superintendent who has general supervision of the maintenance and repair of all highways, bridges, or culverts of the county maintained or repaired from the gravel road repair fund of the county. His term of office is two years but he may be removed by the board of county commissioners. In counties having less than 200 miles of free gravel or macadam roads the county surveyor may act as county highway superintendent.

The board of county commissioners of each county has power to lay out, construct, or improve any public highway or part thereof within such county upon the presen-

¹ In collecting the information for Indiana assistance was rendered by Edward Barrett, State geologist, and collaborator of the United States Department of Agriculture.

tation of a petition signed by a majority of the resident landowners of the county whose lands lie within 1 mile of the proposed improvement and will be benefited thereby. If the board, after investigation, decides to make such improvements, the cost is assessed against the lands within 2 miles of the improvement, in proportion to the benefits accruing. Such assessments are payable in installments of not to exceed 10 per cent per month, but such of the landowners as may prefer may petition that road bonds be issued to cover such portion of the cost as would be assessed against the lands owned by them.

The county board of commissioners of any county, when petitioned by 50 freeholders, voters of any township or townships contiguous to each other, may submit to the voters of such township or townships the question of building the roads described in the petition, by graveling or macadamizing, under the free gravel-road law. A majority vote is necessary to authorize the undertaking of such work. If the work is authorized, the commissioners may issue bonds of the county to pay therefor, the tax necessary to meet the interest and sinking-fund charges on the bonds to be levied upon the taxable property located within the township or townships in which the improvements are made.

Each township trustee is required to divide his township into any suitable number of road districts, not to exceed four, except townships exceeding 36 square miles in area, which may be divided into not exceeding six road districts. Every two years each road district elects a supervisor. In any township in which the township roads do not exceed 10 miles in length, the township trustee is ex officio road supervisor. The road supervisor, subject to the direction and control of the township trustee, has charge of keeping the roads of his district in good repair.

The county board of commissioners of counties maintaining free gravel and macadam roads may levy a tax of not to exceed 1 cent on each \$100 of assessed property valuation for every 10 miles of free gravel and macadam roads in the county, to be used only for the maintenance and repair of such roads. The net proceeds from the registration and licensing of motor vehicles are apportioned to the several counties for road purposes in the following manner: One-third is divided equally among the several counties; one-third is returned to the several counties on the basis of the amount collected in each county, and one-third is apportioned to the several counties in the proportion which the number of miles of free gravel or macadam roads in the county bears to the whole number of such roads in the State.

The township advisory board, on an estimate made by the township trustee, is required to levy annually a road tax of not to exceed 30 cents on each \$100 of taxable property in the township outside the limits of incorporated cities and towns. The amount of such tax assessed to any individual on real estate, up to \$20, may be worked out as far as practicable in the road district in which such real estate lies, and the amount of such taxes assessed on personal property, up to \$20, may be worked out in the district where the owner resides, at the rate of \$1.50 a day for each man, provided that the township trustee may, with the consent of the township advisory board, levy an additional tax of not to exceed 10 cents on each \$100 of taxable property, to be expended by the township trustee for the construction and repair of bridges and culverts, and for other road purposes.

Each able-bodied male resident of each road district, over 21 and under 50 years of age, not exempt by law, is required to work annually from two to four days on the roads, either in person or by able-bodied substitute, or in lieu thereof to pay \$1.50 for each day's labor so required.

There are other special and contingent tax levies and benefit assessments for road and bridge purposes authorized under the law in addition to those mentioned. Various provisions exist under which road bonds may be issued, but the law restricts the amount of such bonds that may be issued, including those outstanding or authorized for issue, to not more than 4 per cent of the total taxable value of the property of the township, townships, or county for whose account the bonds are issued. The

law provides that all road bonds shall be sold by the county treasurer to the highest bidder, but for not less than par.

County prisoners may be worked on the public roads of the county. State convicts may be worked on the public highways of counties upon agreement between the county board of commissioners and the board of trustees of the Indiana reformatory and the board of control of the Indiana State prison.

ROAD MILEAGE.

At the close of 1914 Indiana had 73,347 miles of public road, of which 30,962.40 miles, or 42.2 per cent, were surfaced. Of the surfaced roads, 10,291.29 miles were macadam, 20,264.59 miles gravel, 168.35 miles bituminous macadam, 53.17 miles concrete, 34.75 miles brick, and 150.25 miles sand-clay. There were also reported 17,509.78 miles of graded and drained earth roads. For 1909 Indiana reported 67,996 miles of public road, of which 24,955.75 miles, or 36.7 per cent, were surfaced, indicating a gain in surfaced roads in the five-year period of 6,006.65 miles. Detailed information in regard to road mileage for 1914 is presented in Table 12.

REVENUES APPLIED TO ROADS AND BRIDGES.

The total revenue applied to roads and bridges in 1914 amounted to \$14,233,985.93, as follows: General county tax for road repairs, \$2,022,117.24; township tax, \$1,018,639.26; additional road tax, \$446,975.58; revenues derived from automobile license fees, \$462,811.08; cash value of statute labor tax, \$887,255.79; expended from township bond funds, \$8,989,570.98; expended from county bond funds, principally for bridge construction and repairs, \$406,616. In 1904 there was applied to roads and bridges, \$4,335,108, an increase in the 10-year period of \$9,898,877.93, or 228.34 per cent. Detailed information as to taxation and revenue is presented by counties in Table 35.

ROAD AND BRIDGE BONDS.

The total road and bridge bonds outstanding on January 1, 1915, amounted to \$42,095,357.34, of which \$36,957,686.22 were issued by townships and \$5,137,671.12 by counties.

TOWNSHIP BONDS.

Of the township bonds, \$3,893,221.31 were voted in 1914, and \$7,841,711.53 were sold the same year. The interest rate on the bonds voted and sold in 1914 was 4½ per cent and the term from one to 20 years, the average term being from 10 to 20 years. In 1914 there was expended from township bonds \$8,989,570.98, and \$5,719,416.47 was retired. Detailed information in regard to township bonds is presented in Table 57.

COUNTY ROAD AND BRIDGE BONDS.

The county bonds were issued principally for the construction and repair of bridges, although some have been issued for the purchase of toll roads and for repairs due to floods. In 1914 there were voted \$635,000 and there were sold \$777,294. In the same year \$406,616 was expended and \$237,850 retired.

Information in regard to county bonds was furnished by the State auditor of Indiana, who stated that the information was incomplete.

Details regarding county bonds are given in Table 57A.

IOWA.¹

Iowa has a land area of 55,586 square miles and a total road mileage of 104,074, of which 614.57 miles, or 0.59 per cent, were surfaced at the close of 1914.

There is a State highway commission composed of three members, one of whom is the dean of engineering of the State college of agriculture and mechanic arts and two

¹ The information relative to the State of Iowa was collected, under the direction of this office, by J. H. Ames, State highway engineer, and collaborator of the U. S. Department of Agriculture.

of whom are appointed by the governor from different political parties for terms of four years each. The duties of the State highway commission are to devise, adopt, and furnish standard plans and specifications for highway construction and maintenance; to collect and disseminate information and give instruction and advice to local highway officials; to appoint such assistants as may be necessary and to have general supervision of the county and township road officials of the State. Standard specifications for all bridges and culverts, railroad overhead crossings or subways, must be furnished by the State highway commission to the counties or railroad companies without cost, and all work on such bridges must be done in accordance therewith.

A law of 1913 provides that the board of supervisors of each county employ an engineer or engineers and select and designate from the highways of their respective counties not less than 10 or more than 15 per cent of the main traveled roads of the county, connecting the principal market places of the county and with the county roads in adjoining counties, to be known as the county road system. It is also required that the roads so designated be plainly marked on a map to be furnished by the State highway commission, which finally is forwarded to the State highway commission for consideration and modification or approval. Other roads in the county are to be known as the township road system. If any county fails so to designate the county road system, the State highway commission does so and charges the cost thereof to the county. All surveys, plans, and specifications for the improvement of the roads embraced in the county road system are subject to approval by the State highway commission.

The board of supervisors of each county has general supervision of its roads, with power to establish, vacate, or change them and to see that the laws in relation thereto are carried out. The board of supervisors of any county may establish a permanent road improvement district or districts and cause the highways therein to be improved by grading, draining, paving, or macadamizing and assess not less than 50 per cent of the cost on abutting or adjacent property and may levy a tax not to exceed 2 mills on each dollar of taxable property in the county, including incorporated cities and towns.

Road districts in townships having created such districts are consolidated into one township road district, and all township road funds belonging to these districts are made a general township road fund. The township trustees in all such townships are required to employ a superintendent of the township road system.

Each year the township trustees of each township select from its township road system the roads to be dragged for the year, to be known as "draggable" roads, which shall include all roads in consolidated school districts and all main routes. The township trustees employ a superintendent or superintendents, not exceeding four, who have general supervision of all dragging and repair work on the township road system and make contracts for the dragging of roads. For these purposes there is expended under the direction of the township trustees through the road superintendent not less than the 1-mill drag tax.

Two days' labor on the roads may be required of each able-bodied male between 21 and 45 years of age, not exempt by law, and a penalty of \$3 for each day so required is provided for failure to perform such labor either in person or by able-bodied substitute.

The boards of supervisors of the respective counties levy a tax of 2 mills on the dollar on all taxable property outside the limits of incorporated towns or cities, the proceeds from which constitute the county road-building fund, to be used for the purpose of grading and building roads outside the limits of incorporated cities and towns. The boards of supervisors also levy not more than 1 mill on each dollar of taxable property in their respective counties, including municipalities, for the county-road fund; and on petition of a majority of the electors who are freeholders in any township in the county the board may levy 1 mill additional on property of the

township, to be expended by the board on the roads in such townships; and the boards of supervisors may levy 1 mill additional on all taxable property, including municipalities, for the county-drainage fund, to be used by the board for the drainage of highways and the payment of drainage assessments levied for highway drainage work. One-half of the county road fund arising from the levy on property within any municipality is paid to the treasurer of such municipality, to be used for road and street improvements therein.

The boards of supervisors of the several counties are authorized to make appropriations for bridges as follows: In counties having more than 10,000 and not over 15,000 population, not to exceed \$15,000; in counties having over 15,000 population, not to exceed \$25,000.

Of the proceeds arising from the registration and licensing of motor vehicles, 90 per cent is apportioned to the respective counties in the ratio that the number of townships therein bears to the total number of townships in the State, and 5 per cent is applied for the maintenance and support of the State highway commission.

The township trustees determine each year the rate of property tax to be levied in their respective townships for road and bridge purposes, but the amount of such tax shall not exceed 4 mills on the dollar. The levy of the township road tax is made in the same manner that the other taxes are levied and collected.

Bonds may be issued by counties for bridges across border streams of the State, upon a favorable vote of a majority of those voting at an election called thereon.

Provision is made for working convicts on the roads and in preparation of road material, but no convict who objects shall be so worked.

ROAD MILEAGE.

At the close of 1914 Iowa had 104,074 miles of public road, of which 614.57 miles, or 0.59 per cent, were surfaced. Of the surfaced roads 413 miles were gravel, 171.3 miles macadam, 23 miles sand-clay, 5.77 miles concrete, and 1.5 miles shell. According to the reports received in 1909 Iowa had 102,427 miles of road, of which 2,505.1 were reported as surfaced, thus indicating that the mileage of surfaced roads reported for 1909 exceeds the mileage reported for 1914 by 1,890.53. The figures for 1914 were obtained by the Iowa State Highway Department, and it is believed, therefore, that they are much more accurate than those furnished for 1909. Information in regard to road mileage for the year 1914 is presented in Table 13.

REVENUES APPLIED TO ROADS AND BRIDGES.

The total revenue applied to roads and bridges in 1914 amounted to \$10,187,507.32, exclusive of road bonds and warrants, of which \$3,843,294.94 was derived from a general county and township bridge tax; \$4,128,493.90 from a general county and township road tax; \$896,248.60 from the township drag tax; \$801,258.24 from the motor vehicle tax; \$255,821.64 from the poll tax; \$188,390, the cash value of the statute labor tax, and \$74,000 was appropriated by the State for educational and supervisory work by the State highway commission. Of the latter sum, \$50,000 was for engineering and inspection, \$10,000 for administration, and \$14,000 for miscellaneous equipment, etc. None of these amounts include funds derived from bond issues and road warrants. It was impossible to ascertain the amounts expended from such sources in 1914. In 1904 the total revenue applied to roads and bridges amounted to \$3,106,607.50, thus indicating an increase in the 10-year period of \$7,080,899.82, or 227.92 per cent.

Detailed information in regard to revenue applied to roads and bridges during 1914 is presented in Table 36.

ROAD AND BRIDGE BONDS.

On January 1, 1915, the total road and bridge bonds outstanding amounted to \$1,960,780, of which \$376,828 were voted and sold in 1914. These bonds bear interest at the rate of from 4 to 5 per cent. It was impossible to ascertain the amount expended from these sources in 1914. Information as to bond issues is contained in Table 58.

KANSAS.¹

Kansas has a land area of 81,774 square miles, and a total road mileage of 111,052, of which 1,148.85 miles, or 1.03 per cent, were surfaced at the close of 1914.

The State engineer at the State agricultural college is required to give advice and information on road matters, free of charge, when requested by the county engineer or the board of county commissioners of any county.

The roads of the State are classified as "State roads," which include all roads laid out and defined by the State; "county roads," which include all roads designated as such by the board of county commissioners, and are required, as near as practicable, to connect cities and market centers; "mail routes," which include all free delivery routes; and "township roads," which include all other public highways within the township. The county and State roads are maintained at the expense of the county, and mail routes and township roads, not coinciding with county or State roads, are maintained by the township.

Boards of county commissioners are vested with jurisdiction and general supervision over road and bridge matters in their respective counties. The county board of commissioners of each county is authorized to appoint a county engineer. The county surveyor may be appointed county engineer if the board deems him competent. The county engineer has general supervision of all State and county roads under the authority of the board of county commissioners and of all mail routes and township roads under the direction of the township trustee and highway commissioners.

When 60 per cent of the landowners along any regularly laid out road, who own at least 50 per cent of the land proposed to be taxed, petition the board of county commissioners to improve such road and to assess the cost in not to exceed 10 annual assessments upon the lands lying within the limits stated in the petition, the commissioners cause such improvement to be made and may issue special improvement bonds to pay therefor. If such improvements are made three-fourths of the cost shall be apportioned and assessed against the lands within the limits prescribed in the petition and one-fourth against the township or townships. The board of county commissioners may appoint a superintendent to have charge of such work.

Whenever the board of county commissioners of any county determines that it is necessary to repair or build a bridge or bridges in the county it may appropriate not to exceed \$5,000 for each bridge. If the cost of any bridge exceeds \$5,000 and the assessed valuation of the county is \$15,000,000 or more, additional amounts may be appropriated, graduated according to the assessed valuation.

The board of county commissioners of any county may issue bonds in the county for the building or purchase of a new bridge on petition, signed by not less than 50 voters, requesting the submission of the question to a vote, and the favorable vote of a majority of those voting thereon.

The township trustee, clerk, and treasurer of each township in the State constitute a board of highway commissioners and a township auditing board for their respective townships. All mail routes and township roads are under the supervision and control of the board of highway commissioners, and the board appoints one or more road overseers for all such roads in the township. In order to promote efficiency the board of highway commissioners may employ a superintendent to have charge of all road work under their direction, or may let work to contract.

The board of commissioners of any county may levy for county and State roads and bridges a tax of not more than 1 mill on each dollar of taxable valuation, and, if authorized by a majority vote of those voting at an election thereon, may levy not to exceed 3 mills on each dollar.

¹ In collecting the information for Kansas assistance was rendered by W. S. Gearheart, State engineer, and A. R. Losh, assistant State engineer, and collaborator of the U. S. Department of Agriculture.

The board of highway commissioners in each township shall recommend to the county board of commissioners each year a levy for highway purposes, which shall not exceed 3 mills on each dollar of taxable property in the township.

All males between 21 and 50 years of age are liable to an annual road poll tax of \$3 which may be discharged by the performance of two days' labor on the public roads. The amount of such road poll taxes collected within any city is paid to the city treasurer.

Bonds for bridge purposes may be issued by any county, township, or city in an amount not to exceed, including existing indebtedness, 1 per cent of the taxable property therein, if authorized by a three-fifths vote at an election called thereon.

Authority is given for the working of both State and county convicts on the public highways.

ROAD MILEAGE.

According to reports received, Kansas had at the close of the year 1914, 111,052 miles of public road, of which 1,148.85 miles, or 1.03 per cent, were surfaced. Of the surfaced roads 194.3 miles were macadam, 151.85 miles gravel, 758.5 sand-clay, 30.5 oiled earth, 4.1 brick, 7 shale, 1.35 concrete, and 1.25 cinders. At the close of 1909 Kansas had 98,302 miles of public road, of which 374.71 miles, or .38 per cent were surfaced, thus indicating a gain in surfaced roads of 774.14 miles in the five-year period. Detailed information in regard to road mileage for the year 1914 is presented in Table 14.

REVENUES APPLIED TO ROADS AND BRIDGES.

The total revenue applied to roads and bridges in 1914 amounted to \$5,544,048, of which \$4,847,055 was derived from the general road and bridge tax, \$159,902 from automobile registration fees, \$528,011 from poll tax, and \$9,080 used by the State agricultural college for educational and advisory work in connection with roads and bridges, this latter fund being a part of the appropriation made by the State for the maintenance of the State agricultural college. In 1904 the total revenue applied to roads and bridges amounted to \$1,232,817.45, thus indicating a gain in the 10-year period of \$4,311,230.55, or 349.7 per cent. Detailed information in regard to revenue applied to roads and bridges during 1914 is presented in Table 37.

ROAD AND BRIDGE BONDS.

The only bonds issued in the State of Kansas for road and bridge work were in five or six counties where the work was done under the district road law. It was impossible, however, to secure any information as to the districts which had issued bonds and the amounts that had been issued.

MICHIGAN.¹

Michigan has a land area of 57,480 square miles and a total road mileage of 74,190, of which 7,828.51 miles or 10.55 per cent were surfaced at the close of 1914.

There is a State highway department, which is charged with the duty of giving advice relative to road and bridge construction and maintenance, collecting information and reports from local road officials, and distributing State reward, authorized and appropriated by the legislature for improving the public roads and bridges in the State. The chief officer is the State highway commissioner, who is elected every four years. Whenever any township board, good roads district, or county road commissioner makes application for State reward on any road and requests general plans and specifications, it is the duty of the State highway commissioner to furnish the general plans and specifications requested. When the completed road has been

¹ In collecting the information for Michigan assistance was rendered by Leroy C. Smith, deputy State engineer, and collaborator of the U. S. Department of Agriculture.

passed upon by the State highway commissioner he certifies the fact to the auditor general of the State, who draws a warrant on the State treasurer, payable to the proper authorities in the township, good road district, or county for the amount of State reward due. This varies according to type and width of road, from \$250 to \$1,000 per mile. No State reward is allowed for more than 4 miles in any one township in any one year, but a township or county may improve additional miles of road in a manner to merit State reward and receive the reward each year until the full amount is paid. The State highway commissioner may refuse to grant further reward to any township, good roads district, or county which does not keep its State-reward roads in proper repair.

A system of State reward trunk-line highways has been designated by the legislature. Double State reward is paid for the improvement of the State reward trunk-line highways. The State highway commissioner may refuse further reward where trunk line rewarded roads are not kept in proper repair.

Under the county road law, which may be adopted by a majority vote of those voting at an election thereon, there is elected in each county a board of not more than three county road commissioners. This board is authorized to make any improvement on any road under its control and to employ a county highway engineer, who is required to make all surveys, plans, specifications, and estimates and exercise general supervision over all construction work. Two or more adjoining counties may employ the same engineer. If State reward is to be applied for, the board of county road commissioners is required to file with the State highway commissioner a map of the county showing the location of the proposed system of county roads, which system may be extended, if approved by the State highway commissioner. All State reward roads composing a part of the county road system must be taken over as county roads by the board of county road commissioners. Before October 1 of each year the board of county road commissioners must have preliminary surveys, general plans, specifications, and estimates of roads, bridges, and culverts made by the county highway engineer. From the estimates the board determines the amount of tax to be raised in the county for such year, specifying all the roads upon which the money is to be expended and the amount to be spent on each road, but such tax may not exceed \$3 on each \$1,000 valuation where the valuation does not exceed \$40,000,000; \$2 on the \$1,000 where the valuation exceeds \$40,000,000 but not \$75,000,000; \$1 on the \$1,000 where the valuation exceeds \$75,000,000 but not \$100,000,000; and 50 cents on the \$1,000 if the valuation exceeds \$100,000,000. The board of supervisors levies the tax.

It is made the duty of the board of supervisors to raise a sufficient tax to keep county roads or bridges already built in reasonable repair. Whenever the board of supervisors resolves to issue bonds to raise money for the construction and maintenance of county roads the question may be submitted to an election in which a majority vote is required.

If the owners of a majority of the frontage of lands abutting upon any highway or portion thereof not less than 2 miles in length desire to improve such highway, they may file application to the county road commissioners, who, upon making the improvements, assess from 25 to 75 per cent of the cost on such abutting land according to the benefits accruing, the remainder being assessed to the county and township. All such assessments made in an assessment district may be paid in 10 annual installments and bonds may be issued in anticipation thereof.

By a majority vote at an election for the purpose any combination of townships, villages, or cities lying contiguous in any county may be organized into a good roads district. In each such township, village, or city there shall be elected one good roads commissioner, and these, constituting the board of good road commissioners for the district, have duties in the district like those of the board of county road commissioners in a county under the county road law. The board of good road com-

missioners each year determines the amount of taxes to be levied in the district, which shall not exceed \$3 on each \$1,000 of assessed valuation. Bonds may be issued upon a majority vote at an election.

All public roads in townships, except county roads, are township roads and are under the care and supervision of the township board and a highway commissioner who is elected in each township. The township may be divided into one or more road districts and a road overseer elected in each district.

Highways in every organized township are laid out, improved and maintained by two money taxes. One is known as the road repair tax and shall not exceed 50 cents on each \$100 assessed valuation on all property, outside of incorporated villages, except in townships having an assessed value less than \$200,000, in which the tax may not exceed \$1 on the \$100. The other tax is known as the highway improvement tax and shall not exceed 50 cents on the \$100, including incorporated villages, and may be not to exceed \$1 on the \$100 if the taxable valuation is less than \$200,000. A labor tax of not to exceed one day's labor for each \$100 assessed valuation may be assessed in townships electing to assess such tax. Such labor tax may be discharged by paying \$1.50 for each day assessed.

The township board of any organized township, upon petition signed by not less than 25 freeholders of the township and a favorable majority vote at an election held therefor, may issue bonds in an amount not exceeding 5 per cent of the assessed valuation.

The net fees from the licensing and registration of motor vehicles are applied, 50 per cent to the State highway fund and 50 per cent to the several counties in proportion to the amounts collected therein.

On or before December 1 of each year there is set aside a portion of the appropriation for State highway purposes equal to 2 per cent of the total State rewards that have been paid at that time, which is credited to a repair fund to be paid out after December 1 each year on State-rewarded roads in the same manner as State rewards are paid; but not more than 2 per cent of the total State reward, exclusive of the then current year, paid to any township or county, is paid to such township or county from the repair fund in any one year, provided that all repairs made on such roads shall be in accordance with specifications prepared by or approved by the State highway commissioner.

Authority is given for the working of both State and county convicts on the public highways and in the preparation of road materials.

ROAD MILEAGE.

The total mileage of public roads in Michigan at the close of 1914 amounted to 74,190, of which 7,828.51 miles or 10.55 per cent were surfaced. Of the surfaced roads 1,021.19 miles were macadam, 5,230.25 miles gravel, 1,375.27 miles sand-clay, 107.3 miles concrete, and 94.5 miles bituminous macadam. There were also reported 1,523 miles of graded and drained earth roads. In 1909 there were 86,906 miles of public road, with 6,900.54 miles, or 10.01 per cent, surfaced, an increase of 927.97 miles. Detailed information as to road mileage at the close of 1914 is presented in Table 15.

REVENUES APPLIED TO ROADS AND BRIDGES.

In 1914 there was applied to roads and bridges in the State of Michigan \$9,261,998, of which \$7,080,177 was received from general county and township taxation; \$1,524,557 from local bond funds, and \$657,264 from State funds applied to county and township roads under the State reward system. Of the latter sum \$590,716 was expended for construction of roads and bridges, \$13,035 for maintenance, \$36,167 for engineering and inspection, \$11,808 for administration, and \$5,538 for miscellaneous equipment. In 1904 the total revenue applied to roads and bridges amounted to \$3,179,787.88, an increase in the 10-year period of \$6,082,210.12 or 191.27 per cent. Detailed information on road and bridge revenue for 1914 is presented in Table 38.

ROAD AND BRIDGE BONDS.

The total road and bridge bonds voted and sold in 1914 amounted to \$2,080,742.43. The State highway department estimates that \$1,524,557.49 was expended from bond funds by the various counties and townships. It was impossible to ascertain the amount of county and township bonds outstanding at the close of 1914, but according to Bulletin 136 of the United States Department of Agriculture, the total county and township bonds voted to January 1, 1914, amounted to \$8,308,287. If to this is added the bonds issued by counties and townships in 1914, and if all of the bonds voted up to January 1, 1914, actually were sold, the total outstanding bonds at the close of the year 1914 amounted to \$10,389,029.43. Detailed information as to county and township bonds voted and sold in 1914 and the amounts expended therefrom, also interest rates and terms, is presented in Table 59.

MINNESOTA.¹

Minnesota has a land area of 80,858 square miles and a total road mileage of 93,517, of which 3,967.83 miles, or 4.24 per cent, were surfaced at the close of 1914.

There is a State highway commission of three members, appointed by the governor. The commission appoints a secretary, who must be a civil engineer and practical road builder, and is known as State engineer. He serves during the pleasure of the commission. A deputy and assistant engineers may be employed. The State engineer and his deputy and assistants are required to give engineering advice and assistance to local road officials, to make all necessary surveys, establish grades, and prepare plans and specifications for all State roads. Any county board, subject to the approval of the State highway commission, may designate as a State road any established road or portion thereof outside the corporate limits of a city, village, or borough, and construct or improve it in accordance with the regulations of the State highway commission.

A State tax of 1 mill is levied annually, the money from which, together with all the money accruing from investments in the internal improvement land fund, and all accruing to any State road and bridge fund, however provided, constitutes a general State road and bridge fund, which is apportioned by the State highway commission to the counties so that no county receives less than 1 or more than 3 per cent thereof. The State road and bridge fund is expended only on State roads. The portion which is paid by the State out of the allotment to any county as State aid in the construction of any road or bridge varies from not less than 80 or more than 90 per cent in counties having an assessed valuation of less than \$5,000,000 to not less than 50 or more than 75 per cent in counties having an assessed valuation exceeding \$15,000,000. Twenty per cent of the apportionment to any county is used exclusively for the maintenance of State roads and bridges, the State to pay the same proportion of such maintenance cost as it pays for construction or improvement of State roads. Actual maintenance work is done by the board of county commissioners, in accordance with rules and regulations prescribed by the State highway commission.

The county board of commissioners of each county has jurisdiction and control over county road matters. They may constitute and declare any public highway or road in such county outside of an incorporated city or village a county road and direct and supervise its construction and maintenance.

The town board of each town has general care and supervision of all town roads. Each town constitutes a road district and the town board appoints a competent road overseer who, under its supervision, has charge of the construction and maintenance of all town and county roads therein. The town through which any county road passes maintains and keeps it in repair.

¹ In collecting the information for Minnesota assistance was rendered by George W. Cooley, State highway engineer, and collaborator of the U. S. Department of Agriculture.

The county boards in counties in which there may be territory not organized for township purposes may levy a tax of not to exceed 15 mills on each dollar of assessed value of real and personal property in such unorganized territory for road and bridge purposes. Such levy is made in addition to the levy for county road and bridge purposes and is expended under the direction of the county board. The board of each county may levy not to exceed 3 mills on each dollar of taxable property in the county for the construction and maintenance of State and county roads and bridges. The proceeds of such tax levy is placed in a fund known as the "county road and bridge fund." From this the county appropriates to any town in the county such sums as it deems advisable to aid such town in the construction and maintenance of roads.

The council of any village, borough, or city of the fourth class, or the town board of any town may appropriate and expend reasonable sums to assist in the improvement and maintenance of roads lying beyond its boundaries and leading to it. There may be levied in each town a tax of not to exceed 1 mill on each \$1 of taxable property therein, outside the corporate limits of any borough, city, or village, for a separate fund to be known as the "dragging fund" and to be used for dragging the roads of the town.

The electors of each town at their annual town meeting determine the amount to be raised by taxation for road and bridge purposes in the town, not exceeding 15 mills on each dollar of taxable property. In case of emergency, after the annual town meeting, the town board may levy a tax of not to exceed 5 mills for road and bridge purposes.

Counties and towns may issue bonds for road and bridge purposes when authorized by a majority of those voting at an election thereon.

State convicts may be used in the preparation of road materials and county convicts may be used in performing labor on the public highways.

ROAD MILEAGE.

At the close of 1914 Minnesota had 93,517 miles of public road, of which 3,967.83 miles, or 4.24 per cent, were surfaced as follows: macadam 120.25 miles, bituminous macadam 19 miles, gravel 2,825.25 miles, sand-clay 985.33 miles, brick 0.5 mile, and concrete 17.5 miles. A total of 15,377.5 miles of graded and drained earth roads was reported for 1914. At the close of 1909 Minnesota had 79,323 miles of public road, of which 5,416.85 miles, or 6.83 per cent were reported as surfaced, indicating a loss in surfaced roads of 1,449.02 miles. This apparent loss probably is due to over-estimates of surfaced roads made by the various counties in 1909. The 1914 figures were checked by the State highway department and probably are more accurate than those secured in 1909. Detailed information in regard to road mileage at the close of 1914 is presented in Table 16.

REVENUES APPLIED TO ROADS AND BRIDGES.

The total revenue applied to roads and bridges in 1914 amounted to \$6,458,940.07, of which \$4,388,254.15 was derived from general county and township taxation; \$1,400,000 received from the State by the counties as State aid; \$97,100.92 received from various other sources; \$143,785 appropriated for the maintenance of the State highway department, and \$429,800 expended by counties and townships from local bond funds. The State-aid fund is derived from a 1-mill tax and the amount received from this tax is shown in the last column of Table 39. The total revenue applied to roads and bridges in 1904 amounted to \$1,961,629.24, an increase for the 10-year period of \$4,497,310.83 or 229.26 per cent. Detailed information showing the revenue applied to roads and bridges in 1914 is presented by counties in Table 39.

ROAD AND BRIDGE BONDS.

The total road and bridge bonds outstanding at the close of 1914 amounted to \$1,411,889, of which \$62,000 were voted and \$358,000 were sold in 1914. Expenditure from bond funds in 1914 amounted to \$429,800. There was retired \$49,842. Detailed information in regard to road and bridge bonds is presented by counties in Table 60.

MISSOURI.¹

Missouri has a land area of 68,727 square miles and a total road mileage of 96,041, of which 6,712.57 miles or 6.98 per cent were surfaced at the close of 1914. The roads of the State are classified as follows: class A, intercounty-seat highways, which, when selected and recorded, are known as "State roads;" class B, county public roads, rural route mail roads, or roads that are important laterals to class A roads, and leading to or connecting populous centers; and class C, township roads or roads in the nature of neighborhood roads and not connecting populous centers.

A State highway department exists for the purpose of affording instruction, assistance, and cooperation between the State and counties in the construction, improvement, maintenance, and repair of the public highways. The governor appoints a State highway commissioner for a term of four years. The commissioner, with approval of the governor, appoints one deputy highway commissioner, who is required to be a competent civil or highway engineer. The State highway commissioner, on application of the county court of any county is required to make, or cause to be made, the necessary investigation for the selection and establishment of intercounty highways which become "State roads."

A fund known as "The general State road fund," is created in the State treasury, and all money accruing to the State from any general or special levy of taxes for road purposes, or from any other source whatever, or derived in any way for the construction and improvement of public roads, is credited to such fund, which is apportioned annually to the several counties, districts, and the city of St. Louis, in proportion to the assessed property valuation therein, but no county, district, or city shall receive more than 3 per cent thereof. An equal amount must be raised by such county, district, or city and all expended for the construction or improvement of roads, the plans and specifications for which, if the cost exceed \$1,000 per mile of road or \$500 for a culvert, must be submitted to the State highway commissioner for his approval.

The county courts are vested with jurisdiction and control of all matters relating to public roads, culverts, or bridges, and expenditures therefor. The county court in all counties, except those under township organization, is required to divide the county into suitable and convenient road districts and appoint a road overseer for each district. The court also appoints a county highway engineer annually who may be the county surveyor. The county highway engineer has direct supervision over the public roads of the county and over the road overseers, and the expenditure of all county or district funds by the road overseer. The office of county highway engineer may be abolished on vote of a majority of those voting at an election called thereon.

The county court of counties not under township organization, and township boards in counties under township organization, may divide the territory of their respective counties or townships into special road districts when petitioned to do so by the owners of a majority of the acres of land within the proposed district and after notice and hearing thereon. A board of three commissioners is elected in each such district to serve for a term of three years. This board may levy a general tax for road and bridge purposes on all property in the district, and may issue road and bridge bonds of the district if authorized by a two-thirds vote at an election thereon, the

¹ In collecting the information for Missouri, assistance was rendered by E. W. Sheets, deputy State highway commissioner, and collaborator of the U. S. Department of Agriculture.

amount of such bonds not to exceed, with existing indebtedness, 5 per cent of the assessed valuation. On petition of the owners of a majority in acres of land within one-half mile of a public road or part thereof in such district, praying for the improvement of such road and the assessment of the cost thereof on all lands in the district, payable in not to exceed 15 installments if a county, and not to exceed 20 if a township, the board of commissioners shall have prepared a map of the district and of the proposed road, with plans, specifications and estimates, and shall submit the same to the State highway commissioner for his approval, after which approval the improvements may be made and the cost assessed on the lands. Special assessment bonds may be issued in anticipation of the payment of the assessments so made on the lands.

In counties under township organization the township board is required annually to divide the township into convenient road districts and appoint a road overseer for each district.

A county license tax on dramshops is assessed in amounts of not less than \$250 or more than \$400 each six months, the proceeds of which are set aside as a special road fund in such county and divided among the road districts of the county in proportion to the mileage of public roads in each district.

A stamp tax of 25 cents is imposed on each broker's sale of stocks and bonds of any corporation, or of cotton, petroleum, grain, or other commodities, on a margin or otherwise, and all revenues derived therefrom are set apart for road purposes and distributed among the counties in the same proportion as the school funds.

The county court of all counties, except those under township organization, is required to levy an annual road poll tax of from \$2 to \$6 on each able-bodied male over 21 years and under 50, outside the limits of incorporated cities, towns, or villages, and determine if such tax shall be paid in labor or cash. The court also is required to levy upon all taxable property, real and personal, outside incorporated towns, cities, or villages, a tax of not less than 10 cents nor more than 20 cents on each \$100, which is placed to the credit of the road district from which collected. In addition, the county court, in counties not under township organization, may levy not to exceed 25 cents on each \$100 valuation, the proceeds to go into a special road and bridge fund of the county or township.

The township board, in counties under township organization, annually assesses a road and bridge tax of not to exceed 25 cents on each \$100 assessed property valuation, and credits the proceeds to the district in which collected. The board may levy a poll tax on all able-bodied males over 21 and under 50 years of age residing outside of incorporated cities, towns, or villages, of not less than \$3 nor more than \$6, which may be worked out or paid in cash at the option of the person assessed.

County courts may issue bonds for and on behalf of the townships of their counties in amounts not exceeding, with existing indebtedness, 5 per cent of the assessed valuation of the township for which issued, if authorized by a two-thirds vote of those voting at an election thereon. Also, on petition of 100 tax-paying citizens of a county, the county court may submit the question of issuing bonds of the county for the permanent improvement of roads, bridges, and culverts therein, and may issue such bonds if authorized by two-thirds of those voting.

The net proceeds from the registration and licensing of motor vehicles is paid into the State road and bridge fund.

Authorization is given for the working of county convicts on roads and in the preparation of road materials.

ROAD MILEAGE.

At the close of 1914 Missouri had, according to reports received, 96,041 miles of public road, of which 6,712.57 miles, or 6.98 per cent, were surfaced. Of the surfaced roads, 3,671.5 miles were gravel, 1,442.25 sand-clay, 1,531.05 macadam, 59 bituminous

macadam, 5 cinders, 2.77 concrete, and 1 brick. Missouri also reported 34,706 miles of graded and drained earth road. In 1909 Missouri reported 107,923 miles of public road, of which 4,755.5 miles, or 4.4 per cent, were surfaced, a gain during the 5-year period of 1,957.07 miles of surfaced road. Detailed information regarding road mileage for 1914 is presented in Table 17.

REVENUES APPLIED TO ROADS AND BRIDGES.

The total revenue applied to roads and bridges in 1914 was \$5,513,048.71, of which \$3,508,219.39 was derived from the general road and bridge tax; \$518,416.46 from dramshops; \$23,083.19 from option stamps; \$93,783.58 from automobile revenue; \$175,101.17 from general State funds; \$626,460.27 from special funds, including poll tax, township tax, special taxes, and donations; \$505,418.65 cash value of statute labor tax; \$55,000 from local bond funds, and \$7,566 from State appropriations for the administration of the State highway department.

There are several counties in Missouri under township organization and several in which road work is done by special road districts. An effort was made to secure information as to the amount of revenue applied to roads in such townships and road districts, but with very poor results. The township tax, so far as obtained, is included in the column headed "special funds." It is impossible to estimate the amount of money that was expended for roads and bridges in the townships and road districts from which no reports were obtained. It is obvious, therefore, that Missouri spent more for roads and bridges in 1914 than the above figures indicate.

The total revenue applied to roads and bridges in 1904 amounted to \$2,368,972.79, an increase in the 10-year period of \$3,144,075.92, or 132.72 per cent.

Detailed information as to revenue applied to roads and bridges in 1914 is presented in Table 40.

ROAD AND BRIDGE BONDS.

The total road and bridge bonds outstanding on January 1, 1915, amounted to \$522,500, of which \$75,000 was voted and sold in 1914. Expenditures from bond issues in 1914 amounted to \$55,000, and there was \$37,500 retired. These are principally district and township bonds. No State road and bridge bonds have been issued. Information regarding bond issues is presented in Table 61.

MONTANA.¹

Montana has a land area of 146,201 square miles and a total road mileage of 39,204, of which 609.25 miles or 1.55 per cent were surfaced at the close of 1914.

There is a State highway commission of three members who are the professor of civil engineering of the Montana State school of agriculture and mechanic arts, ex officio; the State engineer, ex officio; and a civil engineer appointed by the governor and acting as secretary to the commission. The commission and its assistants are charged with the duty of giving such advice and assistance regarding road construction, improvement, maintenance, and supervision throughout the State as time and conditions will permit. It keeps on file a map showing all public roads in each county of the State, and in color all roads and proposed roads which it deems of sufficient public importance to receive State aid, and which, when completed, will provide an adequate system of State roads, leading to or connecting the main market and business centers of the State. The commission, acting with the boards of commissioners of the respective counties, classifies such roads into those of primary and of secondary importance, and, unless otherwise ordered, those of primary importance are constructed or improved first. All roads constructed or improved by the aid of

¹ In collecting the information for Montana assistance was rendered by George R. Metlen, secretary of the State highway commission, and collaborator of the U. S. Department of Agriculture.

the State are thereafter known and designated as State roads, and surveys, plans, specifications, and estimates for all work on such roads in the respective counties are required to be made by the board of county commissioners, in accordance with rules and regulations prescribed by the State highway commission and subject to approval by the commission.

Contracts for work on State roads are let by the board of county commissioners, and the work is done under the direction of that board through a competent engineer employed by it and subject to supervision and approval by the State highway commission. The county commissioners report each year to the State highway commission all expenditures on State and county roads and recommend roads for improvement in the succeeding year. The State highway commission makes a biennial report to the governor.

There is a State highway fund from which is deducted each year the sum deemed necessary for the support of the State highway commission, and the balance is apportioned by the commission among the several counties, taking into account the area of each county, the amount expended on its roads, and the extraordinary expenses incident to developing new territory, but none of the fund is expended in the corporate limits of any city or town or in any county which does not provide an equal amount. The net proceeds from the licensing and registering of motor vehicles are applied to the State highway fund.

Boards of commissioners of the several counties have general supervision over the highways and must keep the county divided into suitable road districts and appoint a competent road supervisor for each district. The board also may employ a competent road builder for the county.

The boards of county commissioners may levy in their respective counties a special tax of not to exceed 2 mills on the dollar of all taxable property therein for the purpose of constructing, maintaining, and repairing free public bridges. The boards also levy annually in each county a general tax of not less than 2 or more than 5 mills on the dollar of all taxable property. In addition a general road poll tax of \$2 per annum is levied on each male over 21 years and under 60. All moneys derived from each of the above taxes are credited to the general road fund of the county. Neither of the above taxes applies in an incorporated city or town which levies like taxes for its roads, streets, and alleys.

The county board of commissioners may issue bonds of the county for the construction of highways and bridges in an amount not to exceed, including existing indebtedness, 5 per cent of the value of all taxable property in the county; but no county shall incur indebtedness in excess of \$10,000 for any single purpose unless authorized by a majority of the electors voting in an election thereon. Of the forest reserve moneys received by the State from the United States, 66 $\frac{2}{3}$ per cent is apportioned to the counties entitled to share in the apportionment of the fund in proportion to the acreage of forest reserves in each such county. The amount so apportioned is applied to the general road fund of the county.

Provision is made for the working of county prisoners upon the highways.

ROAD MILEAGE.

At the close of 1914, Montana had 39,204 miles of public road, of which 609.25 miles, or 1.55 per cent were surfaced as follows: Macadam, 78 miles, gravel 514.25, sand-clay 14, and shale 3. There were reported also 6,528.05 miles of graded and drained earth road. At the close of 1909 the State had 23,319 miles of road, of which 95 miles were surfaced, a gain for the 5-year period of 514.25 miles. The mileage data for 1914 is shown in Table 18.

REVENUES APPLIED TO ROADS AND BRIDGES.

The total revenue applied to roads in 1914 amounted to \$2,888,400.61, exclusive of Phillips County, from which no report was received. Of this amount \$1,764,957.88 was received from the general county road and bridge tax, \$1,007,452.02 from county funds left over from 1913 and special funds, \$102,475 from county bond issues, and \$13,515.71 from State motor vehicle fund.

The total revenue applied to roads and bridges in 1904 amounted to \$404,097.81, a gain in the 10-year period of \$2,484,302.80, or 614.77 per cent. Detailed information regarding road and bridge taxation and revenues for 1914 is given in Table 41.

ROAD AND BRIDGE BONDS.

The total road and bridge bonds outstanding on January 1, 1915, amounted to \$2,224,050.72, of which \$462,000 were voted in 1914 and \$440,000 sold the same year. There was expended from bond funds a total of \$102,475 and there was retired \$33,000. All bonds issued in 1914 bear from 5 to 5½ per cent interest and run for 20 years. Detailed information on this subject is presented in Table 62.

NEBRASKA.¹

Nebraska has a land area of 76,808 square miles, a total road mileage of 80,272, of which 1,204.54 miles, or 1.5 per cent, were surfaced at the close of 1914.

There is a State board of irrigation, highways, and drainage, composed of the governor, the attorney general, and the commissioner of public lands and buildings. The board elects a secretary, who must be a civil engineer and is known as the State engineer. The board advises with and aids the county boards in the preparation of plans and estimates and in the supervision of highway work. This is done through an advisory board of three men well versed in road building, together with a secretary who must be a civil engineer and practical road builder and is known as the State highway engineer. These are appointed by the State board, are removable by it, and serve without compensation. Whenever any funds are provided by the State for the construction of roads and bridges, the work is carried on under the direct supervision of the State board of irrigation, highways, and drainage. The advisory board is required to make a biennial report to the governor.

The State board of irrigation is made a State board of supervision for bridges to be located and constructed or purchased under State aid. A tax of one-fifth of 1 mill is levied annually on each dollar of the grand assessment roll of the State for the State-aid bridge fund, to be appropriated by the legislature to aid in the building of bridges across rivers of a width of 175 feet or more, the cost to be paid one-half by the State and one-half by the county. Application for such aid must be made to the State board of irrigation by the county boards. After such bridges are constructed the duty of maintaining them devolves upon the county, unless maintenance cost exceeds \$100, in which event the State pays one-half.

Counties under township organization are divided by the county board of commissioners into seven supervisor districts. Each district elects a supervisor, the seven constituting the county board of supervisors, which divides the county into townships. The town clerk, assessor, and justice of the peace constitute the town board in each township. Each supervisor has charge of the expenditure of funds appropriated by the board out of the county treasury for the roads and bridges within his district. Counties under township organization may vote to have township supervisors, in which event one supervisor is elected from each township and the supervisors thus elected constitute the county board of supervisors. Township boards

¹ The information relative to the State of Nebraska was collected, under the direction of this office, by George E. Johnson, State engineer, and collaborator of the U. S. Department of Agriculture.

each year select one of their number as township highway superintendent to have charge of road and bridge work.

Each county not under township organization is divided into from three to five districts, and one commissioner is nominated by each district but is elected by the qualified electors of the entire county. The commissioners so elected constitute the county board of commissioners. This board has general supervision over the roads of the county, with power to establish and maintain them and to see that the laws in relation thereto are carried into effect. The section lines are made public roads. Each county board divides the county into as many road districts as may be necessary. One overseer of highways is elected in each road district. County boards may appoint a county highway commissioner, who must be a practical and experienced road builder, and who, with the county board, shall have exclusive control and supervision of all the public roads in the county. Road overseers in counties where a county highway commissioner is appointed perform their duties under his direction. The county board is required to divide the public roads of each township or precinct into permanent road-dragging districts and appoint a superintendent of dragging in each township or precinct, who shall cause to be dragged all roads the county board may direct.

Able-bodied males under 50 years of age may be called upon to make emergency repairs on roads and bridges or to clear a mail route of snow. Each person so called upon may be required to furnish a team or tools and implements and is paid for his labor.

All road and labor tax is paid in cash. One-half of all money collected as road tax constitutes a county road fund, which is divided equally among the several commissioner districts for the general benefit of the roads therein, and the other half of such road tax and all labor tax collected constitutes a district road fund and is expended under the direction of the road overseer in the district in which it was collected. The same rate of road taxes may be levied in cities and villages as in the several road districts, but one-half of the proceeds of such taxes so levied and collected in cities and villages shall be paid to the city or village from which collected.

In counties under township organization, the township road tax and the county road tax are paid in cash. All moneys paid into the town treasury from the several districts in discharge of road tax and labor tax constitute a town road fund to be used for the benefit of the road districts of the town, but one-half of the money so collected constitutes a district road fund for use under the direction of the town board in the districts from which collected.

The board of county commissioners, or board of supervisors in counties under township organization, may levy not to exceed 1 mill on each dollar of taxable valuation to be known as the special emergency bridge levy. The county's general tax levy for roads shall not exceed 5 mills on the dollar and for the county bridge fund the levy shall not exceed 4 mills on the dollar. A tax is imposed on inheritances and the proceeds in each county applied to the improvement of its roads. The net proceeds from the registration and licensing of motor vehicles are paid into the county treasury and applied to road construction, dragging, and repair work. One-fifth of the whole amount of the forest reserve fund annually paid to the State by the United States Government is apportioned to the road funds of the counties entitled to share in the apportionment of the funds.

On petition of a majority of the resident freeholders of any road district, precinct, or township, the county board shall levy not less than 5 nor more than 25 mills upon each dollar of taxable property therein, the proceeds of which become a part of the road fund of such district, precinct, or township.

Towns are authorized to purchase toll bridges and, if other funds are insufficient, to issue bonds to an amount not exceeding 10 per cent of the assessed value of all tax-

able property therein to pay for them. The bond issue must receive the favorable vote of two-thirds of those voting at an election called thereon.

Any county, township, precinct, city, or village, when authorized by three-fifths of those voting at an election thereon, may issue bonds in an amount not exceeding 10 per cent of the taxable value of all property therein for the purpose of building bridges across any boundary river.

Townships, precincts, cities, or villages, respectively, may issue bonds in amounts not to exceed 10 per cent of their taxable valuation for roads and bridges, when authorized by a vote of two-thirds of those voting at an election called thereon.

Provision is made for the improvement of roads in counties of more than 20,000 population on petition to the county boards, signed by the owners of a majority of the frontage of lands abutting on such roads, and for the payment of the cost of such improvement by the issuance of county bonds, the interest and principal of such bonds to be paid by special benefit assessments on lands lying within 2 miles of the road or roads improved.

State prisoners work on the roads, streets, or alleys.

ROAD MILEAGE.

At the close of 1914 Nebraska had 80,272 miles of public road, of which 1,204.54 miles or 1.5 per cent were surfaced. Of the surfaced roads 1,131.1 miles were sand-clay, 39.21 miles macadam, 21 miles gravel, 7.53 miles concrete, 2.4 miles brick, 1.3 miles bituminous macadam, and 2 miles gypsum. There was also reported 27,540.90 miles of graded and drained earth road.

In 1909 Nebraska reported 80,338 miles of public road, of which 248.55, or .31 per cent were surfaced, a gain in surfaced roads in the 10-year period of 955.99 miles.

Detailed information as to road mileage for 1914 is presented in Table 19.

REVENUES APPLIED TO ROADS AND BRIDGES.

The total revenue applied to roads and bridges in 1914 amounted to \$1,796,277.69, of which \$1,454,680.65 was derived from general county and township taxes, \$85,399.77 from poll taxes, \$114,724.44 from inheritance taxes and other special taxes, \$47,086 from the automobile fund, and \$94,386.83 from the State-aid bridge fund. The total revenue applied to roads and bridges in 1904 amounted to \$878,547.40, a gain in the 10-year period of \$917,730.29, or 104.4 per cent. Information regarding road and bridge revenue and taxation for these purposes is presented by counties in Table 42.

BONDS.

No State bonds have been issued for roads and bridges and so far as can be ascertained, no bonds have been issued for these purposes by counties or townships.

NEVADA.¹

Nevada has a land area of 109,821 square miles, a total road mileage of 12,182, of which 262 miles or 2.14 per cent were surfaced at the close of 1915.

By a law enacted in 1913, a board of county highway commissioners was created in each county to be composed of the regularly elected board of county commissioners, the county assessor, and the district attorney. The board is vested with exclusive control of all matters pertaining to the construction, repair, and maintenance of public highways, roads, and bridges within the county, and may appoint a county road supervisor, who, under the direction of the board, has charge of all county roads, and supervises and directs construction, repair, and maintenance. If the county board of highway commissioners decides not to appoint a county road supervisor, it

¹ In collecting the information for Nevada assistance was rendered by Parvin P. Jones, collaborator of the U. S. Department of Agriculture.

may appoint a board of from one to three road commissioners for each district to have like duties as those prescribed for the supervisor. The respective boards of county highway commissioners were required by law to lay out and designate, on or before September 1, 1913, the roads in the county which accommodated the greatest amount of travel and were of most importance to the people generally. Such roads were to be designated as main county roads. The board also was required to designate the other roads in the county accommodating general public travel, and these roads were to be designated as general county roads. Where the cost of any work of improvement exceeds \$500, it is the duty of the board of county highway commissioners to have plans and specifications prepared therefor, and to let the same to contract to the lowest responsible bidder.

For the purpose of creating a fund to be known as the county road and bridge fund, to be used in the construction, repair, and maintenance of county roads and bridges, and the purchase of necessary machinery and equipment, the county boards of commissioners are authorized to issue bonds of their respective counties in an amount not to exceed 3 per cent of the total assessed value of real and personal property therein, after having submitted the proposition for a majority vote of the qualified electors.

The boards of county commissioners are authorized, on petition of a majority of the taxpayers of any township, or townships, to divide such township or townships into a road district or road districts. Road districts so created shall be disorganized by the board of county commissioners upon petition of a majority of the taxpayers. Road funds for such districts are obtained by applying thereto the net proceeds of the county's proportion of all poll taxes collected from citizens residing within such road district, and also the proceeds of the one-fourth of one per cent county road taxes levied and collected within such district; and, when a majority of the property holders of the district shall petition the county commissioners so to do, an additional special tax may be levied in an amount not to exceed \$3 on each \$1,000 valuation; provided, that persons liable to such special tax may pay a part or all of it in labor on the roads at the rate of \$3 for each full day's work with tools and implements, \$4 for each team of two animals and \$1 for each additional animal.

The legislature has passed at different times laws designating certain roads to be State highways and imposing upon the respective boards of county commissioners the duty of constructing and maintaining such highways.

A general county road tax of not to exceed one-fourth of one per cent upon the taxable property of the county is authorized to be levied by the board of county commissioners and the proceeds expended in each district in proportion to the amount collected therein. The net proceeds from the registration and licensing of motor vehicles is applied to the maintenance of roads in the several counties, each county being entitled to such proportion of the fund as was collected therein.

Provision is made for the working of both county and State convicts upon the highways. Such detail, however, is voluntary on the part of the convict. An appropriation has been made to create a general road fund from which to pay the expenses incident to the working of State convicts on the roads.

ROAD MILEAGE.

At the close of 1915 Nevada had 12,182 miles of public road, of which 262 miles, or 2.14 per cent, were surfaced. Of the surfaced roads 193 miles were gravel, 67 miles sand-clay, and 2 miles macadam. There were also reported 1,080 miles of graded and drained earth road. In 1909 Nevada reported 12,751 miles of public roads, of which only 46 miles, or 0.36 per cent, were surfaced, a gain in surfaced mileage the 6-year period of 216 miles. Detailed information regarding road mileage in 1914 is presented by counties in Table 20.

REVENUES APPLIED TO ROADS AND BRIDGES.

The total revenue applied to roads and bridges in 1915 amounted to \$245,013.65, of which \$173,730.86 was derived from the general county taxes, \$54,026 from poll taxes, and \$17,256.79 from county bond issue. It was impossible to secure this information for the year 1914. No funds were devoted to road improvement by the State during the years 1914 or 1915. In 1904 the revenues applied to roads and bridges amounted to \$46,875.85, a gain for the 11-year period of \$198,137.80, or 422.68 per cent. Detailed information showing the revenues applied to roads and bridges in 1915 is presented in Table 43.

ROAD AND BRIDGE BONDS.

The total road and bridge bonds outstanding January 1, 1915, amounted to \$38,000, of which \$25,000 were voted and sold in 1914. In the early part of 1915 there was expended from bond funds \$17,256.79. Road bonds amounting to \$3,000 were retired in 1914. No State road and bridge bonds have been issued. Detailed information on this subject is presented in Table 63.

NEW MEXICO.¹

New Mexico has a land area of 122,503 square miles, and a total road mileage of 11,873, of which 261.5 miles or 2.2 per cent were surfaced at the close of 1914.

There is a State highway commission consisting of the governor, the commissioner of public lands, and the State engineer. The governor is chairman, the commissioner of public lands is secretary, and the State engineer is engineer of the commission. The commission has charge of the expenditure of the State road fund, is authorized to employ, remove, and fix the salaries of assistant engineers and other necessary help, is empowered to make rules and regulations governing the method of construction, improvement and maintenance of such highways and bridges as may receive aid from the State and to compel compliance therewith, and, when requested, is required to advise towns, villages, and counties regarding the construction and maintenance of any road or bridge therein. It also is made the duty of the commission to investigate the needs of the various localities of the State and to determine what roads shall be constructed or repaired, and cooperate with the boards of commissioners of the various counties in the construction of such roads. It is further required of the commission that it construct, repair, and maintain at the expense of the State, either wholly or in part, such highways as in its judgment will best subserve the interest of the general public and result in the ultimate development of a complete system of highways in the State.

At various times the legislature has designated specific roads as State highways and provided for their improvement either by cooperation with the counties through which they pass, by an appropriation from the State treasury, or by the labor of State convicts. Where such highways are provided, the counties are required to provide the necessary rights of way; and in the case of the "El Camino Real" the boards of commissioners of the counties through which it passes are authorized and required to levy a special tax of not to exceed 2 mills on the dollar on all taxable property in their respective counties to be used for the construction of bridges within such counties.

There is in each county a county road board composed of three qualified electors and taxpayers, appointed by the State highway commission for a period of three years. The members serve without compensation and are subject to removal by the State highway commission. The county road board has authority to construct or improve, or to aid in constructing or improving, any road or bridge within the county and to maintain and repair the same, and is required to select and lay out, in cooperation

¹ In collecting the information for New Mexico assistance was rendered by James A. French, State engineer, and collaborator of the U. S. Department of Agriculture.

with the State highway commission a system of prospective county highways to include the main traveled roads of the county, together with those leading to the county seat and to such other towns, settlements, and railroad stations as may be deemed advisable. Each such board is directed to employ a surveyor to prepare, in accordance with instructions of the State highway commission, a map showing the system of prospective county highways which must meet at the county lines so as to make continuous and direct lines of travel between the counties.

A State tax of 1 mill is levied each year and the proceeds are paid into the State treasury to the credit of the State road fund. Also, one-half of the net proceeds from licensing and registering motor vehicles is applied to the State road fund. In addition a State tax of one-fourth mill is authorized to be levied and the proceeds used in carrying out the provisions of the acts providing for constructing the highway known as the "El Camino Real."

The board of county commissioners of each county is authorized to levy a general road tax of not to exceed 3 mills on each dollar of assessed valuation.

At the general election in 1912, a State bond issue of \$500,000 was authorized, to be sold as needed by the State highway commission for the construction of the State system of highways.

All able-bodied males between 21 and 60 years of age are required to pay an annual road tax of \$3, or in lieu thereof to work three days on the roads.

On petition of 100 legal voters and taxpayers, the board of county commissioners may levy a special tax of not to exceed $1\frac{1}{2}$ mills for the purpose of creating a county road fund. Also, one-half of the net proceeds from licensing and registering motor vehicles is apportioned to the several counties in proportion to the amounts collected in each, and applied to the county road fund.

On petition for the building of a public bridge signed by taxpayers to the number of 400 in class A counties, 200 in class B counties, and 100 in class C counties, the county board of commissioners may levy to pay therefor taxes limited in amounts, according to the classification of the several counties, as follows: \$25,000 in class A counties, \$10,000 in class B counties, and \$3,500 in class C counties.

Bonds for road and bridge purposes may be issued by the board of county commissioners of any county in an amount not to exceed 4 per cent of the assessed value of all property therein, if authorized by a majority vote at an election thereon.

ROAD MILEAGE.

At the close of 1914 New Mexico had, according to the reports received, 11,873 miles of public road, of which 261.5 miles, or 2.2 per cent, were surfaced. Of the surfaced roads 184 miles were gravel, 72.5 miles sand-clay, and 5 miles bituminous macadam. There also was reported 1,906.5 miles of graded and drained earth road. At the close of 1909 New Mexico had 16,920 miles of public road, of which 104 miles, or 0.61 per cent, were surfaced, an increase of 157.5 miles of surfaced roads. Detailed information as to road mileage in each county at the close of 1914 is presented in Table 21.

REVENUES APPLIED TO ROADS AND BRIDGES.

In 1914 there was applied to roads and bridges a total of \$556,398.82, of which \$357,955.15 was derived from the general State and county road and bridge tax; \$16,871.69 from the forest reserve fund; \$63,320.46 from special bridge levies; \$42,280.64 from a \$3 personal tax; \$29,970.88 from county levies for special roads; \$30,000 from bond issue funds in Dona Ana County; and \$16,000 from automobile licenses, expended by the State. The forest reserve fund is applied to roads and schools, but it was impossible to ascertain how much of the amount given above was expended for schools. The total revenue applied to roads and bridges in 1904 amounted to \$165,651.56, an increase in the 10-year period of \$390,747.26, or 235.88 per cent. Information as to revenue applied to roads during 1914 is presented by counties in Table 44.

ROAD AND BRIDGE BONDS.

The total road and bridge bonds outstanding on January 1, 1915, amounted to \$157,000, of which \$50,000 was voted and sold in 1914. There was expended in 1914 in Dona Ana County \$30,000. In 1913 the State authorized the issuance of \$500,000 State bonds for road and bridge purposes, but the funds derived from this issue did not become available until September 1, 1915. These bonds are issued in denominations of \$1,000 each, numbered from 1 to 500, the first 20 of which are payable on January 1, 1915, and 20 bonds in consecutive order on July 1, annually, thereafter. The proceeds are to be expended for the construction and maintenance of a system of State highways.

Detailed information on this subject is presented in Table 64.

NORTH DAKOTA.¹

North Dakota has a land area of 70,183 square miles and a total road mileage of 68,796, of which 955 miles, or 1.38 per cent, were surfaced at the close of 1914.

There is a State highway commission composed of the governor, the State engineer, and one other member appointed by the governor. The State engineer, as secretary, is required to keep all records of the commission, to give such advice, assistance, and supervision in respect to road construction as time and conditions will permit, and to prepare plans and specifications for and superintend the construction of any road, under the direction of the State highway commission, when requested so to do by the board having jurisdiction over such road. The State highway commission requires the State engineer to prepare a map of each county showing the roads and the location of all bridges and culverts, and also the roads on which it is proposed to utilize State funds when such funds may be made available. When requested by any board of county commissioners, or by any board of township supervisors, the State engineer is required to prepare plans for the construction of any bridge or culvert or to examine and report on any existing bridge or culvert, and cooperate as far as possible with the county surveyor or county superintendent of highways.

The construction and maintenance of roads and bridges in the several counties is vested in the county board of commissioners. Such jurisdiction in civil townships is vested in the township board of supervisors. The board of county commissioners in any county not formed into townships is required to apportion the county annually into one or more road districts and appoint a road supervisor for each district. The boards of county commissioners of the several counties may appoint biennially a competent engineer or practical road builder, who may be the county surveyor, to be county superintendent of highways, and to have charge of the road work within the county.

By an act passed in 1915 there is in each county a board of highway improvements, consisting of one member from each road district in the county. It is the duty of this board to formulate plans and methods for the uniform working of highways within the county, and such method as it may adopt shall be followed in each district of the county.

The township board of supervisors is required to appoint annually one township overseer of highways, who must be a practical road builder. He has charge of the construction and maintenance of all highways and township bridges in the township. In unorganized territory in counties where no county superintendent of highways has been appointed, the board of county commissioners shall appoint a district overseer of highways, whose powers and duties shall be the same as in the organized townships.

¹ In collecting the information for North Dakota assistance was rendered by Jay W. Bliss, State engineer, and collaborator of the U. S. Department of Agriculture.

A tax not to exceed 5 mills on the dollar for road purposes and 4 mills on the dollar for bridge purposes may be levied in each county. A road poll tax of \$1.50, or one day's labor, upon all male persons between 21 and 50 years of age not exempt by law also may be levied.

In each county having a population of 2,000 or more, according to the latest Federal census, there shall be levied and collected a tax of not less than one-fourth mill or more than 4 mills on the dollar, the proceeds to go into a county road fund, to be used only for grading, ditching and surfacing the principal thoroughfares of the county.

Township supervisors may levy for road and bridge purposes a tax of not to exceed \$1 on each \$100 of assessed valuation.

The net proceeds from licensing and registering motor vehicles are returned to the counties from which collected for the purpose of maintaining the main-traveled roads.

Authority is given for working State convicts upon the public highways.

ROAD MILEAGE.

At the close of 1914 North Dakota had, according to the reports received, a total of 68,796 miles of public road, of which 955 miles or 1.38 per cent were surfaced with gravel. There was also reported 25,306 miles of graded and drained earth roads. At the close of 1909 North Dakota had 61,593 miles of public road, of which 140 miles or 0.23 per cent were surfaced; a gain of 815 miles of surfaced road in the 5-year period. Information showing mileage of roads at the close of 1914 is presented in Table 22.

REVENUES APPLIED TO ROADS AND BRIDGES.

The total revenue applied to roads and bridges in 1914 amounted to \$2,402,383.52, of which \$2,016,419.64 was received from the general county and township tax; \$44,900.60 from automobile licenses; \$84,092.95 from poll taxes paid in cash; \$214,233.58 from special road and bridge funds and other sources, and \$42,686.75 which represented the cash value of the property poll tax worked out upon the public roads. The total revenue applied to roads in 1904 amounted to \$550,340.72, a gain in the 10-year period of \$1,852,042.80 or 436.52 per cent. Information showing the revenues applied to roads and bridges during the year 1914 is presented in Table 45.

No road and bridge bonds have been issued by the State, counties or townships in North Dakota.

OHIO.

Ohio has a land area of 40,740 square miles, a total road mileage of 86,354, of which 30,569.17 miles or 35.16 per cent were surfaced at the close of 1914.

The governor appoints a State highway commissioner for four years unless sooner removed by the governor. The State highway commissioner appoints three deputy commissioners, each of whom must be a competent civil engineer. One is designated chief highway engineer. One of the deputy commissioners has supervision of all road construction work, another of all road maintenance and repair work and the third of all bridge and culvert construction, maintenance, and repair work. Necessary division engineers may be appointed by the State highway commissioner. The State highway commissioner is vested with general supervision of the construction, improvement, maintenance, and repair of all intercounty highways and main market roads, and the bridges and culverts. Upon the request of county or township road officials, he gives engineering advice and assistance and causes surveys, plans, specifications, and estimates to be prepared for the construction, maintenance and repair of roads, bridges or culverts.

The State highway commissioner was required by the legislature to designate and report to the governor a system of intercounty highways; and the legislature has designated a system of main market roads, which follow along and upon the route

or portions of the system of intercounty highways. The State highway commissioner may designate additional intercounty highways and main market roads, or change existing ones.

A State tax of three-tenths of 1 mill on all taxable property in the State is levied annually, and the proceeds constitute a State highway improvement fund. Of this fund 75 per cent is used for the maintenance of the State highway department and for apportionment equally among the several counties to aid in the construction, maintenance and repair of the intercounty highways, and 25 per cent is used to aid in the construction, maintenance and repair of the main market roads. The county commissioners are required to make application to the State highway commissioner for State aid before January 1 of the year for which the funds are available and if they do not make application by such date the township trustees may do so. The county or township, and the State each pay one-half of the cost of improvements made with the aid of State funds unless the county or township agrees to pay a larger portion; and of the county's portion the county pays, except as otherwise provided, 50 per cent, the township 30 per cent, and abutting property 20 per cent.

The county commissioners of the several counties are vested with general jurisdiction over the roads in their respective counties. Applications to locate, alter, vacate, or otherwise affecting a public road, are made by petition to the county commissioners. The county surveyor is made the county highway superintendent, who may be designated by the State highway commissioner to have charge of the highways, bridges and culverts in the county under the control of the State, in which event one-fifth of his salary is paid by the State. If the State highway commissioner deems the county highway superintendent of any county improperly qualified and so states in writing to the county commissioners, he may then designate an engineer to have charge of the construction, improvement and repair of all bridges and highways within such county. On or before April 1 each year, the county highway superintendent reports to the county commissioners an estimate of the probable amount required within the year for the construction, maintenance and repair of bridges, culverts and roads, and also makes an annual estimate to the township trustees of the funds needed for the construction, maintenance and repair of bridges, culverts, and roads in the township.

The board of county commissioners of any county may construct a new road or improve any existing road when requested by a petition signed by at least 51 per cent of the land or lot owners, residents of the county, who will be specially taxed or assessed for such improvements. Of the cost of such improvements, a part or all may be assessed against abutting real estate and the balance, if any, shall be paid by the county and township, or townships, as determined by the board of county commissioners. In order to meet the county's portion of the cost, the county commissioners are authorized to levy a tax of not exceeding 2 mills on the dollar of taxable property in the county; and in order to provide funds with which to meet the township's portion the county commissioners may levy a tax of not exceeding 3 mills on the taxable property of such township or townships. Bonds of the county may be issued in anticipation of the collection of such taxes and assessments.

Toll roads may be purchased by the boards of county commissioners in their respective counties, when authorized by a majority of those voting at an election thereon. Bonds may be issued for toll roads so purchased.

Three township trustees are elected biennially in each township, which is divided into not less than one or more than four road districts, and the trustees appoint for each road district a superintendent, who is known as township highway superintendent and has control of the roads of his district. The township highway superintendent is under the control and direction of the township trustees and may be removed for incompetence or neglect of duty. He divides the gravel and unimproved public roads into road dragging districts of not more than 6 miles of road each, and contracts for dragging.

The public highways of the State are divided into three classes, State roads, county roads, and township roads. State roads include intercounty highways and main market roads improved or taken over by the State, and are maintained by the State highway department. County roads are such as are improved, or that may hereafter be improved, by the county, or heretofore built by the State and not a part of the system of intercounty highways and main market roads, together with such roads as are, or may be constructed by the township trustees to conform to the standard for county roads as fixed by the county commissioners, and all such roads are maintained by the county commissioners. Township roads include all other public highways, and are maintained by the township trustees, but the county commissioners may assist in maintaining such roads.

To provide funds to enable counties and townships to pay their portion of the cost of roads built with State aid, the county boards of commissioners may levy a tax of not to exceed 1 mill on all taxable property in the county and township trustees may levy not to exceed 2 mills on all taxable property in the township. The county commissioners may issue bonds of the county in anticipation of the taxes which may be levied, the amount not to exceed the sum of the county, township and land assessment portions of the cost of State-aid highways.

After the annual estimate for the county has been filed with the county commissioners by the county highway superintendent, as required by law, the county commissioners, after having made such changes or modifications as they deem desirable, may levy for the purposes set forth in the estimate a tax of not to exceed 2 mills upon each dollar of taxable property in the county; and after the annual estimate for each township has been filed with the trustees of the township, they may levy a tax of not to exceed 2 mills upon each dollar of taxable property in the township outside the limits of incorporated villages or cities.

The trustees of any township may levy and assess upon each dollar of taxable property therein a tax of not exceeding 3 mills for the purpose of improving, dragging, repairing, or maintaining any public road, or roads, or parts thereof. The trustees designate the roads within the township to be improved, and direct the county highway superintendent to make necessary surveys, plans, specifications, and estimates. If the funds raised by the levy be insufficient, the trustees may issue bonds of the township if authorized by a favorable vote of a majority of the qualified electors of the township who participated in the last preceding election for governor. The trustees may assess all or any part of the cost of making such improvement against the land not more than 1 mile from either side or terminus of the road or roads improved.

The owners of real estate in any township may petition the township trustees for the construction, reconstruction, or improvement of any public road, or part thereof, in such township, and for the assessment, according to the benefits, of from 25 to 50 per cent of the cost thereof on the real estate within 1 mile, or within one-half mile, on either side or terminus of such road or part thereof.

The funds derived from the registration and licensing of motor vehicles is applied to the maintenance and repair of the intercounty highways and the main market roads of the State.

Authority is granted for the working of State prisoners on the intercounty highways and main market roads. They may be worked also on the county roads, and county and municipal convicts may be worked upon the public roads and streets.

ROAD MILEAGE.

At the close of 1914 Ohio had 86,354 miles of public road, of which 30,569.17 miles or 35.16 per cent were surfaced. Of the surfaced roads 12,903.87 miles were macadam, 1,066.29 bituminous macadam, 15,385.93 gravel, 640.41 brick, 315.67 concrete, 211 sand-clay, and 46 miscellaneous. In addition, there were reported 15,280 miles of graded and drained earth roads. At the close of 1909 Ohio had, according to reports

received, 88,861 miles of public road, of which 24,106 miles or 27.13 per cent were surfaced, an increase in surfaced road mileage in the five-year period of 6,463.17 miles. Detailed information on this subject is presented in Table 23.

REVENUES APPLIED TO ROADS AND BRIDGES.

The total revenue applied to roads and bridges in 1914 amounted to \$14,334,245.98, of which \$5,266,081.98 was derived from the general county and township tax; \$796,476.72 from the State-aid fund disbursed to counties; \$1,072,413.95 expended by State highway department in addition to disbursements to counties; \$6,384,355.74 expended from county and township bond issues; and \$814,917.59 from other sources. The total revenue applied to roads and bridges in 1904 amounted to \$5,706,083.61, an increase in the 10-year period of \$8,628,162.37, or 151.2 per cent. Detailed information on this subject is presented in Table 46.

ROAD AND BRIDGE BONDS.

The total road and bridge bonds outstanding in 1914 amounted to \$31,175,968.53. These were county and township bonds. There was expended from county and township bonds in 1914, \$6,384,355.74; there was retired \$2,684,593.81. In the same year \$8,702,303.46 was voted and \$8,593,303.46 sold. Detailed information on this subject is presented in Table 65.

OREGON.¹

Oregon has a land area of 95,607 square miles and a total road mileage of 36,819, of which 4,726.4 miles, or 12.81 per cent, were surfaced at the close of 1914.

There is a State highway commission composed of the governor, as chairman, the secretary of state and the State treasurer. Until 1915 the commission appointed a State highway engineer. In that year the legislature abolished that office, creating the elective one of State engineer, who supervises and directs all State road work, advises and assists the county courts when so requested in all road and bridge matters, and selects trunk or State roads leading to the chief market centers, and so far as possible connecting with the principal county roads of the State, to be submitted to the State highway commission as a suggested system to be improved at State expense. The State highway commission appoints a chief deputy to the State engineer, to have immediate charge of highway work. A State tax of one-fourth of a mill is levied on all property in the State and the proceeds constitute the State road fund, which is expended under the direction of the State highway commission.

The county court has jurisdiction over all county road matters, divides the county into suitable and convenient road districts annually, and appoints a road supervisor for each. The county surveyor, who is elected, surveys and lays out roads under the direction of the county court. A board of viewers recommends action on such roads to the court. A county road master, who has general supervision of all road matters under the direction of the county court, may be appointed each year by the court.

A tax of not to exceed 10 mills on the dollar on all taxable property in the county, the proceeds of which shall be set aside as a general road fund to be used in the improvement and construction of county roads or bridges on county roads, may be levied by the county court. Seventy-five per cent of the funds thus derived are apportioned to the several road districts in the county in proportion to the taxable valuation of each district. The resident taxpayers of any road district in a county may vote an additional tax for road purposes. District road meetings legally called have power to determine what, if any, county roads or portions thereof in the road district are to be improved in any special manner and to levy a special tax of not to exceed 10 mills on the dollar on all taxable property in the district to pay for them. Improvements so made are under the control of the county court.

¹ In collecting the information for Oregon, assistance was rendered by G. Ed Ross, collaborator of the U. S. Department of Agriculture.

Bonds may be issued by any county for road construction when authorized by the favorable vote of a majority of those voting at an election thereon. Such bonds are limited in amount not to exceed 2 per cent of the assessed valuation of the county.

The net proceeds from the licensing and registration of motor vehicles is returned to the several counties in proportion to the amount collected in each county and applied to road purposes.

Both State and county convicts may be used on the public roads.

ROAD MILEAGE.

At the close of 1914 Oregon had a total of 36,819 miles of public roads, of which 4,716.40 miles, or 12.81 per cent, were surfaced. Of the surfaced roads 1,000.72 miles were macadam, 137.25 miles bituminous macadam, 3,060.15 miles gravel, 179.50 plank, 300 sand-clay, 28.41 concrete, 10 volcanic cinders, and 0.37 wood block. There were also reported 4,718.75 miles of graded and drained earth road. The total of all public roads in 1909 was 29,475 miles, of which 2,799.25 miles, or 9.49 per cent, were surfaced, an increase in surfaced mileage in the five-year period of 1,917.85 miles. Detailed information regarding road mileage for 1914 is presented by counties in Table 24.

REVENUES APPLIED TO ROADS AND BRIDGES.

The total revenue applied to roads and bridges in 1914 amounted to \$5,310,466.76. Of this \$3,259,245.59 was derived from the general county tax, \$679,832.92 from other sources, \$1,122,817.65 was expended from county bond issue funds, \$238,570.60 was obtained from the State road tax, and \$10,000 was appropriated by the State for salary, office and field expenses of the State engineer. Of the amount obtained from other sources \$59,761.18 was derived from motor license fees and applied to county roads. The total revenue applied to roads and bridges in 1904 amounted to \$796,375.97, an increase for the 10-year period of \$4,514,090.79, or 566.84 per cent. Detailed information on this subject is presented by counties in Table 47.

ROAD AND BRIDGE BONDS.

The total county road and bridge bonds outstanding January 1, 1915, amounted to \$1,615,000, of which \$1,122,817.65 was expended in 1914. In the same year \$1,365,000 was voted and sold. No State road bonds have been issued. Information regarding road and bridge bonds is presented by counties in Table 66.

SOUTH DAKOTA.¹

South Dakota has a land area of 76,868 square miles, and a total road mileage of 96,306, of which 363 miles, or 0.37 per cent, were surfaced at the close of 1914.

There is a State highway commission composed of three members, one from each congressional district, appointed by the governor. The work of the commission is of an advisory nature. Any county board may designate any established road or specified portion in its county as a State road, subject to the approval of the commission, and may construct or improve it in accordance with the regulations of the commission.

Each organized county of the State has a board of county commissioners. In counties not formed into townships, the board of county commissioners is required to divide the county annually into one or more road districts and appoint a road supervisor for each district. Each road supervisor has charge of highway and bridge work in his district, subject to the supervision and direction of the county commissioners.

Every road located by State or county authorities is a county road. The county commissioners have general supervision of county roads and have power to appro-

¹In collecting the information for South Dakota, assistance was rendered by Homer M. Derr, State engineer, and collaborator of the U. S. Department of Agriculture.

priate such sums from the county treasury as they think advisable for improving them; but these appropriations shall not be greater in any one year than the ratio of \$1,000 to each \$500,000 of assessed valuation of real estate in the county. Additional sums may be appropriated to assist in building bridges and for opening and repairing county roads when authorized by the people. The towns through which any county road passes are required to keep the road in repair.

In counties having township organization one supervisor is elected each year at the annual town meeting. The supervisors constitute the board of supervisors and have charge of the roads and bridges in the townships. They divide their respective townships into as many road districts as they may deem convenient and appoint a road overseer for each district.

On petition of 5 per cent of the resident freeholders of any township, the question of abolishing the highway labor tax and the requirements relating thereto may be submitted to a vote. A majority of those voting shall determine such election. If the highway labor tax is abolished, all road taxes, poll and property, must be paid in cash. A township may, by like proceedings, return to the labor system.

All road taxes collected as personal taxes from residents of any incorporated city or town, and all road taxes collected on real or personal property in such city or town, shall be paid to the treasurer and be used in improving its streets or bridges, or roads leading thereto.

Whenever one-third of the resident taxpayers of any county petition the board of county commissioners for an appropriation to build a bridge across any navigable river on the line of said county, the board publishes a notice and holds a hearing. It may thereupon appropriate not to exceed one-half of the cost of the bridge.

The proceeds derived from the national forests in the State are apportioned to the counties in which national forests are located in proportion to the area of the forests in each county, and 50 per cent of the amount so apportioned is applied to road purposes.

The county board of commissioners may submit to a general or special election the question of raising a sum greater in amount than can be raised by the annual tax levy authorized for constructing any road or bridge. A favorable vote of a majority of the voters of the county is required to authorize such levy, which shall not exceed 1 mill on the dollar of assessed valuation.

The county commissioners annually levy, in addition to the road taxes levied by the several townships, a road tax of not to exceed 5 mills on the dollar, and, if authorized by a majority of the electors of the county, such levy may be not to exceed 10 mills; but in 1915 a law was passed changing the levy not to exceed 2 mills, and not to exceed 5 mills when authorized by a majority of the electors of the county. The county commissioners may levy in unorganized townships in their respective counties not to exceed 8 mills on each dollar of assessed valuation, the proceeds to be expended within the unorganized district.

Upon petition of two-thirds of the residents of a county owning two-thirds of the acreage abutting on any earth road, the county commissioners may improve the road by macadamizing, oiling, or graveling. The cost is assessed on the abutting lands to the extent of the benefits accruing to such lands, and the balance of the cost is paid by the county. Where such work is done, the county commissioners are authorized to employ the county surveyor or a competent engineer to do the necessary surveying and prepare plans, specifications, and estimates.

The county commissioners levy yearly for county roads not exceeding 2 mills on the dollar on all property, not including that within the limits of any organized township or of any organized city or town. For county bridges the levy does not exceed $1\frac{1}{2}$ mills, except that in counties where only part of the county is organized into civil townships the levy shall not be greater than $1\frac{1}{4}$ mills in the organized townships. Also, in all counties not wholly organized into civil townships, the county commis-

sioners shall levy on each male between 21 and 50 years of age not exempt by law a road poll tax of \$1.50, which may be paid in cash or by one day's labor.

Of the fees received for licensing and registering motor vehicles 85 per cent are placed in the county motor-vehicle fund to be expended for highway and culvert purposes outside the limits of cities and towns.

The electors of each township, at the annual March town meeting, vote to raise such sums for constructing bridges and for highway labor and road taxes as they may deem expedient and the township supervisors must levy the taxes so authorized; but such road tax shall not exceed 50 cents on each \$100 of assessed valuation. There may be assessed annually against each male, not exempt by law, between 21 and 50 years of age a road poll tax of \$1.50 or one day's labor. Any road tax levied by the board of county commissioners in addition to the poll tax may be worked out at \$1.50 a day in the road district in which the person assessed resides, if a personal tax or a tax on personal property, and in the road district where the real property is situated if a tax on real property. Township taxes, poll and property, are payable in cash, unless a majority of the electors at a town meeting vote that such taxes may be paid in labor.

When a petition is presented to the board of supervisors of any organized town, signed by two-thirds of the legal voters thereof, praying for a certain amount of money to be raised for the construction of any road or roads, ditch or ditches, or similar work, the supervisors issue and sell bonds for the amount specified, but not in excess of 5 per cent of the taxable valuation of the town nor in any case more than \$5,000.

Provision is made for working county convicts on the public roads.

ROAD MILEAGE.

At the close of 1914 South Dakota had, according to the reports received, 96,306 miles of public road, of which 363 miles, or 0.37 per cent, were surfaced. Of the surfaced roads 212 miles were gravel, 129 sand-clay, 10 bituminous macadam, and 12 surfaced with other materials. There were reported also 17,071.5 miles of graded and drained earth road.

In 1909 South Dakota reported 56,354 miles of public road, of which 286 miles, or 0.5 per cent, were surfaced, a gain in surfaced roads of 77 miles. Information regarding road mileage is presented by counties in Table 25.

REVENUES APPLIED TO ROADS AND BRIDGES.

The total revenue from all sources applied to roads and bridges in 1914 by the various counties and townships in South Dakota amounted to \$1,217,809.42. This does not include Clark, Edmunds, and Haakon Counties, from which it was impossible to obtain information. The total revenue applied to roads and bridges in 1904 amounted to \$383,283.07, a gain for the 10-year period of \$834,526.35, or 217.73 per cent. Information in regard to revenue applied to roads and bridges in the year 1914 is presented by counties in Table 48.

No State, county or township road and bridge bonds are outstanding at present in South Dakota.

UTAH.¹

Utah has a land area of 82,184 square miles and a total road mileage of 8,810, of which 1,153.75, or 13.09 per cent, were surfaced at the close of 1914.

The State road commission consists of the governor, the State engineer, the State treasurer, one member of the faculty of the agricultural college of Utah and one member of the faculty of the University of Utah, all serving without compensation. The State road commission designates a system of State roads, has charge of the expenditures of the State road fund, aids the boards of county commissioners by furnishing

¹ In collecting the information for Utah, assistance was rendered by E. R. Morgan, State road engineer, and collaborator of the U. S. Department of Agriculture.

plans, specifications and estimates for culverts and bridges, and road construction work, tests road materials, conducts experiments, keeps all records, maps, profiles, and papers, and submits a biennial report to the governor.

On or before June 1 each year the State road commission gives notice to the county board of commissioners of any county of its intention to engage in State road construction work in that county. Within 30 days the county commissioners notify the commission whether or not they will comply with the requirements of the notice. Should they fail to comply with the requirements in the time specified, with further time of 30 days, the county forfeits its right to its portion of the State road fund for that year. The State road commission makes all plans, specifications and estimates for the improvement of any State road, and may have such work done by contract. County commissioners are required to secure the right of way for any State road located within their respective counties.

The legislature makes an annual appropriation for the State road fund, which is made available by law for the construction and maintenance of State roads in each county in equal proportions, the counties being required to duplicate from one-fourth to the full amount of their apportionment, depending upon the class of the county. The net revenues derived from the registration and licensing of motor vehicles is also applied to the State road fund. The county board of commissioners of each county is authorized to appropriate funds or to levy a special road tax on all assessable property in the county sufficient to duplicate its apportionment of the State road fund, and in like manner to raise additional funds for the purpose of expediting the construction and maintenance of the State roads therein, such additional funds to be expended under the direction of the State road commission; but the total levy that may thus be made in any county shall not exceed 5 mills in any one year.

The board of county commissioners has power to lay out, maintain, control, erect and manage the public roads and bridges within the county, outside of incorporated cities. The board enacts all laws, ordinances, and regulations not in conflict with the law of the State, for the control, construction, alteration, repair and use of all such public roads and highways; grants licenses and franchises for constructing and keeping in repair roads, bridges and ferries, and for the taking of tolls thereon.

The county commissioners are authorized to appoint biennially a county road commissioner, who has charge of the public roads of the county, submits to the board of county commissioners plans, specifications, and estimates for the improvement of county roads within the county and has charge of the execution of such work, and assists in supervising and constructing State roads under the direction of the State road commission. He also is required to keep free from obstructions and in good repair all public roads in the county and to collect the road poll tax.

In 1909 a law was passed to establish a standard system of construction of public highways. Under it there was adopted and designed a profile of cross sections for 4-rod, 5-rod, 6-rod, 7-rod and 8-rod highways to be observed and conformed to in all work upon public roads in the State. Where physical conditions would not permit such construction, the State engineer was required to prepare plans and specifications to meet the conditions.

The county board of commissioners may divide the county into special road districts for the purpose of graveling, macadamizing or paving any State or county road. The cost of such work is assessed at so much per acre, or fraction thereof, upon the lots and lands abutting upon the roads improved, but the assessment shall not be made until notice shall have been given, and, if desired, opportunity for hearing granted.

A road poll tax of \$2 is assessed annually upon each man over 21 and under 50 years of age, not physically incapacitated or exempt by law. The funds thus derived are expended by the county board of commissioners in the improvement of the roads of the county. The road poll tax may be collected in incorporated cities or towns and expended on their roads and streets.

The county board of commissioners of each county is authorized to levy taxes upon the taxable property of the county for all county purposes within the limitations prescribed by statute, and upon the taxable property within any district for the construction of roads and highways and for other purposes, but no such district tax shall be levied except upon a favorable vote at an election in which a majority of the qualified electors of the district who paid a property tax the next preceding year vote.

Where the streets of any city are or may become a part of the system of State roads, such city may levy a special tax of not to exceed 2 mills, to be expended in connection with the State road fund under the direction of the State road commission.

County boards of commissioners may contract bonded indebtedness after submitting the proposition at a general or special election. Four weeks' notice of such election must be given, and the favorable vote of a majority of those voting is required. No county, however, shall become indebted in an amount, including existing indebtedness, exceeding 2 per cent of the value of the taxable property therein.

Prisoners in the county jail may be required to work on the county roads, and convicts in the State prison may be required to work on State roads.

ROAD MILEAGE.

According to the reports received, Utah had at the close of 1914 a total of 8,810 miles of public road, of which 1,153.75 miles, or 13.09 per cent, were surfaced. Of the surfaced roads, 685.75 miles were gravel, 401 miles sand-clay, 49 miles macadam, 15.5 miles bituminous macadam, and 2.5 miles concrete. Reports also showed 2,403.11 miles of graded and drained earth roads. In 1909 Utah had 8,320 miles of road, of which 1,018 miles, or 12.23 per cent, were reported as surfaced, an increase in surfaced mileage in the five-year period of 135.75 miles. Detailed information regarding road mileage in 1914 is given in Table 26.

REVENUES APPLIED TO ROADS AND BRIDGES.

The revenue applied to roads and bridges in 1914 amounted to \$803,070.63, of which \$263,561.23 was derived from the general county tax, \$374,878.13 from general county funds, poll taxes, and other sources, \$157,732 from State appropriations, and \$6,899.27 from county bond-issue funds. This does not include the revenue applied to roads and bridges in Carbon and Utah counties, from which it was impossible to obtain reports. The total revenue applied to roads and bridges in 1904 amounted to \$218,675.78, an increase for the 10-year period of \$584,394.85, or 267.24 per cent. Information regarding revenue applied to roads in 1914 is presented by counties in Table 49.

ROAD AND BRIDGE BONDS.

The total road and bridge bonds outstanding on January 1, 1915, amounted to \$541,500, of which \$281,500 were county bonds and \$260,000 State bonds. In 1914 there was expended from county bond issues \$6,899.27, and there was voted and sold \$10,500. The State bonds were issued in 1911. They bear 4 per cent interest and are to be paid off by the deferred serial method between 1922 and 1934. Detailed information regarding county bond issues is presented in Table 67.

WASHINGTON.¹

Washington has a land area of 66,836 square miles, and a total road mileage of 42,428 of which 4,922.09 miles, or 11.61 per cent, were surfaced at the close of 1914.

There is a State highway commissioner, appointed by the governor for a term of four years. There also is a State highway board, composed of the governor, the State highway commissioner, the State auditor, the State treasurer, and a member of the

¹ The information for Washington was collected under the direction of this office by W. R. Roy, State highway commissioner, and collaborator of the U. S. Department of Agriculture.

public service commission, appointed by the governor. The construction and maintenance of State highways is under the jurisdiction of the State highway board, of which the State highway commissioner is secretary and executive officer. The State highway commissioner may employ such engineering and other assistants as may be necessary in the prosecution of State road work and in the performance of other duties imposed by law upon his office. He is required to advise local road officials in all road and bridge matters.

State highways are divided into two classes: Primary and secondary, in the order of their importance. The general route of these roads is established by the legislature, which also makes specific appropriations for their improvement from the funds derived from taxes. Primary roads are constructed and maintained by the State, while secondary roads are constructed by the State and maintained by the counties.

Permanent highways are defined to mean improved public roads constructed along a main line of travel, either beginning at some trade center or an extension of an existing road beginning at some trade center. The individual owners of two-thirds of the linear feet of land fronting on any public highway or section thereof may petition the board of county commissioners for the improvement of the road. After submission by the board of county commissioners of a resolution for the improvement the State highway commissioner passes upon it, and the county engineer makes surveys, plans, specifications, and estimates. Fifteen per cent of the cost of the improvements, or as much more as may be stated in the petition of land owners, is assessed against the land lying within not less than 660 feet and not more than 3 miles on each side of the center line of the highway, which assessment may be discharged in one payment, or in 10 annual installments, and bonds issued in anticipation of the payment. A State tax of $1\frac{1}{2}$ mills on the dollar is levied, and the proceeds credited to the permanent highway fund, which is used for the construction and maintenance of permanent highways in the several counties in proportion to the amount of such fund collected in each county.

The boards of county commissioners of the several counties have general supervision over the roads in their respective counties. They divide the county, or any part thereof, into suitable and convenient road districts, and appoint a road supervisor for each district. Each county commissioner is ex officio road commissioner on the several road districts in his commissioner district, and must see that all orders of the board of county commissioners with reference to roads in his district are carried out. The road supervisor, under the direction of the board of county commissioners, is required to keep all roads and bridges of his district free from obstructions and in as good repair as the available funds will permit.

The county engineer is elected for a term of two years, and is required to be a competent civil engineer and surveyor. He makes surveys and prepares plans, specifications and estimates of all roads ordered to be improved, and recommends to the board of county commissioners road and bridge improvements to be made, together with the estimated cost.

On petition of the owners of two-thirds of the linear feet frontage on any county road, the county board of commissioners may cause such road to be improved and assess the cost on the lands especially benefited thereby.

A State tax of 1 mill is levied annually, and the proceeds placed in the public highway fund. Of the taxes so levied and collected, $7\frac{1}{2}$ per cent are set aside annually by the State treasurer to be used exclusively under the direction of the State highway commissioner for the repair and maintenance of roads already established and constructed.

All net proceeds from the licensing and registration of motor vehicles are credited to the permanent highway fund and distributed to the several counties in proportion to the amounts paid by each into said fund, to be used for the maintenance and repair of permanent highways.

For the purpose of raising revenue for the construction, maintenance, and repair of county roads, bridges, and wharves, the board of county commissioners annually levies a tax of not to exceed 4 mills on all taxable property in the county, the proceeds going into the general road and bridge fund. There also is levied a tax of not to exceed 10 mills on the taxable property in each road district to constitute a district road fund.

County boards of commissioners may issue bonds for road purposes in an amount not to exceed 5 per cent of the taxable valuation of all property in their respective counties, when authorized by a three-fifths vote of those voting at an election thereon.

County and State convicts may be worked upon the public highways, and State convicts may also be worked in the preparation of road material. The legislature makes appropriations to defray the expenses of equipping and operating quarries for the purpose of preparing road materials by convict labor.

ROAD MILEAGE.

Washington had, at the close of 1914, 42,428 miles of public roads, of which 4,922.09 miles, or 11.61 per cent, were surfaced. Of the surfaced roads 502.82 miles were macadam, 165.52 miles bituminous macadam, 3,924.48 miles gravel, 83.50 miles sand-clay, 26.35 miles brick, 79.42 miles concrete, and 140 miles surfaced with other materials. There were also reported 9,450.76 miles of graded and drained earth road.

The total of public roads reported for 1909 was 34,284 miles, of which 4,520.68 miles, or 13.19 per cent, were surfaced, an increase in surfaced roads of 401.41 miles. Information regarding the total and surfaced mileage of roads in each county for the year 1914 is shown in Table 27.

REVENUES APPLIED TO ROADS AND BRIDGES.

The total revenue applied to roads in 1914 amounted to \$7,944,717.38. Of this \$7,128,934.47 was derived from the general tax for State, county, township, and district roads, \$509,146.50 from county and district road bonds, \$261,636.41 from other sources, and \$45,000 from State appropriations for the maintenance of the State highway department. The above items do not include expenditures for the maintenance of State quarries for which the legislature in 1913 appropriated a revolving fund of \$200,000. Receipts from the licensing and registration of automobiles were not applied to roads in 1914.

The total revenue applied to roads and bridges in 1904 amounted to \$1,436,070.19, an increase for the 10-year period of \$6,508,647.19, or 453.22 per cent. The amounts received from general taxation for State, county, and township roads and bridges, and other revenue applied to this purpose in 1914 are shown by counties in Table 50.

ROAD AND BRIDGE BONDS.

The total county and district road and bridge bonds outstanding on January 1, 1915, amounted to \$1,555,000, of which \$509,146.50 was expended in 1914. In that year there was voted \$133,274.27 and \$35,000 of road and bridge bonds sold. No State road bonds have been issued, but \$190,000 State bonds were issued in 1911 for the construction of a bridge across the Columbia River at Wenatchee. Information regarding road and bridge bonds is shown by counties in Table 68.

WISCONSIN.¹

Wisconsin has a land area of 55,256 square miles, and a total road mileage of 75,707 of which 13,399.47 miles, or 17.6 per cent, were surfaced at the close of 1914.

There is a State highway commission which consists, ex officio, of the State geologist and the dean of the engineering college of the State university, and of three other

¹ The information for Wisconsin was collected under the direction of this office by A. R. Hirst, State highway engineer, and collaborator of the U. S. Department of Agriculture.

members appointed by the governor for six years each. The commission has charge of all matters pertaining to the expenditure of State funds in the improvement of public roads and bridges, advises towns, villages, and counties in the construction of roads or bridges, makes regulations for surveying, planning, constructing, and inspecting all roads constructed under the State-aid law, which regulations must be observed by counties in order to render them eligible to receive State aid, reviews the prospective State highways selected by the county boards and may alter them to make the systems of adjoining counties connect into continuous and direct routes, and, on request of the county board of any county, takes direct charge of the construction and maintenance of State-aid roads and bridges in such county.

The county board of each county not having already done so is required to select a system of prospective county highways to be known as the county system of prospective State highways and to embrace, at first, not to exceed 15 per cent of the road mileage of the county and include the main-traveled roads leading into each town in the county. The county and towns together pay not less than $66\frac{2}{3}$ per cent of the cost of improvement and the State pays the balance. If the county system of prospective State highways is constructed by the county and State alone, the county pays 60 per cent and the State 40 per cent of the cost.

All State highways shall be maintained at the expense of the county in which they are located, except that such portions as pass through or lie within incorporated villages shall be maintained by such villages. The legislature appropriates funds for the support of the State highway commission and for State aid, and requires such State tax to be levied as is necessary to raise the sums appropriated. The appropriation for State aid is apportioned among the counties of the State in proportion to the ratio which the assessed valuation of each county bears to the total assessed valuation of the State and is used for the purpose of improving the county system of prospective State highways.

By an act passed in 1915, there is appointed by the railroad commission of Wisconsin, subject to approval by the governor, a State chief engineer who is required to have a general knowledge of the subject and profession of engineering and may be removed by the governor for cause after hearing. The chief engineer has charge of and supervision over all engineering or architectural work performed by or for the State or by or for any of the departments, boards, or commissions of the State, and is required to furnish engineering and architectural services to any branch or department of the State government upon request.

Each county board annually elects a committee of not less than three nor more than five members, to be known as the county State road and bridge committee. Such committee is authorized to purchase and sell county-road machinery, as authorized by the county board, to determine whether each piece of State road and bridge construction in the county shall be let by contract or done by day labor and to enter into such contracts, to direct the expenditure of all maintenance funds, to audit all claims in connection with the construction of State-aid roads and bridges, to assist in the letting and to approve all contracts for county-aid bridges costing over \$500.

The county board of each county selects a county highway commissioner, who must pass examination by the State highway commission. The county highway commissioner has charge, under the direction of the county committee, of the construction of all highways built with State or county aid and of the maintenance of all State highways. He is required to make an annual report to the State highway commission and to the county board.

Whenever any highway, road or street passes through or connects two or more towns, cities, villages or parts thereof, the county board may adopt the same as a trunk road for the purpose of improving it. In order to improve such road an assessment district may be formed which may include property not abutting upon such highway, road, or street, but tributary thereto and benefited thereby. One-third of the cost of im-

proving such highway, road or street may be assessed against the property in such assessment district in proportion to the benefits accruing.

The annual town meeting in each town elects three supervisors, who constitute the town board of supervisors and have the care and supervision of all highways therein, except as otherwise provided by law. The town board divides the town into districts and appoints a superintendent of highways for each district. The superintendent of highways, under the direction of the town board, has charge of the construction and repair of highways and bridges in the town.

The annual town meeting determines by vote if highway taxes shall be paid in money or in labor. Unless the town has voted in favor of paying the highway taxes in labor, it may direct that the money derived from such taxes be expended under the direction of the town board, or by three highway commissioners to be elected for that purpose. The supervisors of each town in which the highway taxes are payable in labor may appoint a suitable person to oversee and direct the road work and exercise supervision over all superintendents of highways therein.

The county board shall levy each year a tax of not over 2 mills on all taxable property in the county to maintain the county road and bridge fund, which tax shall be in addition to all other highway taxes, and the proceeds shall be expended in building the prospective system of State highways. The county board may raise money for the original improvement of any portion or portions of the system of prospective State highways by issuing bonds of the county in such amount, including existing indebtedness, as will not exceed the constitutional limit; provided that the amount of bonds that may be issued shall not exceed one-fifth of 1 per cent of the total assessed valuation of the county, unless authorized by a majority of the electors voting at an election thereon.

The qualified electors of each town have power at any annual town meeting to raise money for the construction and repair of roads and bridges and for other charges and expenses of the town, but the total taxes levied in any town for any one year for all town purposes, exclusive of schools, shall not exceed 1 per cent of the total assessed valuation of such town, unless a larger sum is needed for building and repairing highways and bridges, in which case the electors may vote and the proper authorities may levy not to exceed one-fourth of 1 per cent in addition to the 1 per cent.

When the amount of highway taxes assessed by the supervisors shall be deemed insufficient to keep the highways in repair, it shall be lawful for them, upon written application of the superintendents of highways, to assess an additional tax of not to exceed 7 mills on each dollar of the assessed valuation of the town. The supervisors may also levy a tax on all taxable property in the town for the purpose of opening or repairing highways, but such tax shall not exceed \$600 in any year.

Highway taxes of not less than 1 nor more than 7 mills on the dollar shall be levied on the real and personal property of each superintendent district, provided that there may be levied any additional amount which may be authorized by the last preceding annual town meeting, not exceeding 10 mills in all.

Every able-bodied male between 21 and 50 years of age, not exempt by law, may be assessed by the town board of supervisors to pay a road poll tax of \$1.50.

Every superintendent of highways shall call out as many taxpayers as may be necessary to clear highways blocked by snow, and the taxpayers shall be credited against highway taxes for the work so performed. If taxpayers perform labor exceeding in value the highway taxes assessed against them for the year they are compensated for their work.

The town board, upon favorable vote at the annual town meeting, designates roads to be known as "drag roads," divides them into sections, and appoints a dragman for each section. The board levies a tax of not exceeding 1 mill to pay for such dragging.

Owners of land abutting on any prospective State highway or section thereof, 1 mile or more in length and extending back on either side one-fourth of a mile or less, who

desire that such highway or section thereof be improved, may, as an inducement, provide for paying part of the town's portion of the cost by agreeing to have such land specially served taxed for not exceeding five years at a rate not to exceed \$10 for each 80 rods of the respective frontages. If the improvements are made special bonds may be issued for the amount of the assessments on the lands and shall be a tax lien on all the lands.

Of the net proceeds from registering and licensing motor vehicles, 25 per cent is applied to the State highway fund and 75 per cent to county-road work.

County bonds to aid the county road and bridge fund may be issued to an amount, including existing indebtedness, not exceeding 1 per cent of the total assessed valuation of the county.

Any town, if a majority of the electors thereof shall so authorize at an election thereon, may issue bonds in any amount not exceeding the constitutional limit for the original improvement of any portion or portions of the system of the prospective State highways.

State convicts may be worked on the public highways and county convicts may be worked in preparing road materials.

ROAD MILEAGE.

According to reports received, Wisconsin had, at the close of 1914, 75,707 miles of public road, of which 13,399.47 miles, or 17.6 per cent were surfaced. Of the surfaced roads 9,597 miles were gravel, 2,054 miles sand-clay, 1,408 miles macadam, 183 miles bituminous macadam, 83.07 miles concrete, 2.4 miles brick, and 72 miles were surfaced with other materials. Wisconsin also reported 30,927 miles of graded and drained earth roads. In 1909 Wisconsin reported 61,090 miles of public road, of which 10,167.33, or 16.64 per cent, were surfaced, an increase from 1909 to 1914 of 3,232.14 miles of surfaced road. Detailed information regarding road mileage is presented by counties in Table 28.

REVENUES APPLIED TO ROADS AND BRIDGES.

The revenue applied to roads and bridges in 1914 amounted to \$9,880,240.50, of which \$7,882,838 was received from general county and township taxes; \$1,454,704 from the general State tax apportioned to counties; \$95,497.50 was the cash value of the poll and labor taxes; \$87,000 was appropriated from the general State funds for administration and engineering work done by the State highway commission; \$320,000 was received from local funds left over from 1913, and \$40,201 was expended from local bond issue funds. In 1904 there was expended on roads and bridges \$2,181,262.38 an increase for the 10-year period of \$7,698,978.12, or 352.26 per cent. Information showing receipts from taxation for road and bridge purposes during the year 1914 is presented in Table 51.

ROAD AND BRIDGE BONDS.

The total county and township road bonds outstanding on January 1, 1915, amounted to \$281,078, of which \$21,500 was voted and sold in 1914. Bonds amounting to \$16,050 were retired, and there was expended from bond funds \$40,201. No State bonds have been issued for road and bridge purposes. Information regarding local bond issues is presented in Table 69.

WYOMING.¹

Wyoming has a land area of 97,594 square miles, and a total road mileage of 14,797, of which 468.50 miles, or 3.1 per cent, were surfaced at the close of 1914.

By certain acts the legislature designated and established a State system of public highways to be constructed, repaired and maintained by the labor of convicts in

¹ In collecting the information for Wyoming assistance was rendered by C. D. Shawver, deputy State engineer and collaborator of the U. S. Department of Agriculture.

the State penitentiary, under the State commission on prison labor. It was made the duty of the commission to use all such convicts as it might deem practicable for that purpose. The work was to be done under the supervision of competent persons selected by the commission. The roads constituting the State system of public highways were to be located and surveyed under the direction of the State engineer, appointed by the governor. It also was made the duty of the State engineer to cause plans and specifications for their construction, repair and maintenance to be prepared, to select the materials of which such roads should be constructed, and to furnish a deputy engineer, whose salary and legitimate expenses should be paid by the respective counties in which work might be done. The State engineer certifies to the State commission on prison labor each month the expense rendered and incurred in respect to said highways during the preceding month in each county through which the same may pass, and the boards of county commissioners pay to the State engineer the amount due for the work done in their respective counties out of the road fund or general fund of the county. Boards of county commissioners secure the right of way for such highways and construct necessary bridges, in accordance with the plans of the State engineer; provided that, as far as practicable, bridges across small streams shall be constructed by the use of convict labor.

The board of county commissioners of each county is vested with power and jurisdiction over the laying out, alteration or discontinuance of public highways therein. The boards also have jurisdiction over the granting of licenses for keeping ferries, toll bridges, and toll gates. The boards divide their respective counties into road districts and when the county is so divided a district road supervisor is elected for each district. If the county be not divided into road districts a county road supervisor is elected.

Bridges between counties may be constructed by the counties interested, each county to pay one-half, or other pro rata share, of the cost. If such cost will burden the road and bridge fund unreasonably, or if it will exceed \$5,000, the board of county commissioners may cause a portion to be paid out of the road and bridge fund of the county and may levy a special tax, not exceeding 2 mills on each dollar of taxable property in the county, to raise the balance.

An inheritance tax is provided, the proceeds of which in each county are to be expended for the permanent improvement of the county roads outside the limits of incorporated cities and villages. The county boards are authorized to levy a tax of not to exceed 3 mills on each dollar of taxable property in the county, the proceeds of which constitute a general county road fund. At the time of making the annual levies for county purposes the county board may levy upon each able-bodied man between 21 and 50 years of age, not exempt by law, a special poll or road tax of \$2, which may be paid in cash or by one day's labor on the roads. If the funds thus derived be insufficient for the work in any road district, the county board may appropriate necessary additional funds from the general road fund. The proceeds of the special poll or road tax, collected from persons residing within incorporated cities or towns of the State, are paid into the treasury of such cities or towns.

The net proceeds from the registration and licensing of motor vehicles is paid to the county from which collected, to be expended for the temporary improvement of the county roads outside of the limits of incorporated towns or cities.

The county boards of commissioners are authorized to work prisoners confined in any county jail upon the public highways of the county.

ROAD MILEAGE.

At the close of 1914 Wyoming had, according to reports received, a total of 14,381 miles of public road, of which 52.5 miles, or 0.36 per cent, were surfaced with gravel. There were also reported 1,672 miles of graded and drained earth roads. In the Yellowstone Park, which is located in the northwest corner of the State, there are 416

miles of Government roads, practically all of which are surfaced with gravel or stone. If this mileage is included, the total mileage for the State at the close of 1914 amounted to 14,797, of which 468.5 miles, or 3.1 per cent, were surfaced. In 1909 Wyoming had 10,569 miles of road, of which only 416 miles in the Yellowstone were surfaced, thus indicating a gain in surfaced mileage during the five-year period of 52.5 miles. Detailed information regarding road mileage for 1914 is given in Table 29.

REVENUES APPLIED TO ROADS AND BRIDGES.

The total revenue applied to roads and bridges in 1914 amounted to \$669,661.16, of which \$423,215.31 was derived from county funds, \$6,237 from a State appropriation for the equipment of State convict road camps, and \$240,208.85 from United States Government appropriations for repair and betterment of roads in the Yellowstone National Park. The latter sum was expended under the direction of the Corps of Engineers of the United States Army. The county revenues were obtained principally from general county funds, automobile licenses, and poll taxes. The total amount applied to roads and bridges in 1904 amounted to \$345,931.73, an increase for the 10-year period of \$323,729.43, or 93.58 per cent. Information regarding revenue applied to roads and bridges during 1914 is presented in Table 52.

No county or State bonds have been issued in Wyoming for road and bridge purposes.

APPENDIX A.

The following are the tables referred to in the foregoing text giving information as to road mileage in the States discussed.

ARIZONA.

TABLE 7.—Mileage of public roads outside of incorporated cities and towns, 1914.

County.	Total mileage of all roads.	Surfaced roads.							Graded and drained earth.	
		Mac- adam.	Bitumi- nous mac- adam.	Gravel.	Sand- clay.	Other hard- sur- faced roads.	Total of sur- faced roads.	Per- cent- age of roads sur- faced.		Increase in surfaced mileage over 1909.
Apache.....	350			20	30		50	14.28		100
Cochise.....	1,734		3.5	4			7.5	.43	- 14.5	58
Cocoonino.....	1,544			40		150	90	5.82	83	295
Gila.....	546.5			6.5			6.5	1.18	6.5	40
Graham.....	298								- 3	23
Greenlee.....	200			40			40	20	40	60
Maricopa.....	2,260		10			28	18	.79	- 16	1,140
Mohave.....	550	1				1	1	.18	1	80
Navajo.....	600			1			1	.16	- 11	30
Pima.....	1,550	.73		14.2			14.93	.96	14.93	23.96
Pinal.....	400									200
Santa Cruz.....	200	5					5	2.50	5	11
Yavapai.....	523								- 20	135
Yuma.....	1,319.5	4.5			15		19.5	1.47	-105.5	500
Total.....	12,075	11.23	13.5	125.7	45	58	253.43	2.09	- 19.57	2,695.96

¹ Cinders.

² 1 mile, concrete; 7 miles, oil and caliche (gravel).

CALIFORNIA.

TABLE 8.—Mileage of public roads outside of incorporated cities and towns, 1914.

County.	Total mileage of all roads.	Surfaced roads.							Graded and drained earth.
		Concrete.	Macadam.	Bituminous macadam.	Gravel.	Sand-clay.	Oiled earth.	Total of surfaced roads.	
Alameda.....	533	33.79	62.7	17.33	215.09			328.91	61.75
Alpine.....	200								- 35
Amador.....	580		5		400			417.8	34.81
Butte ¹	1,200	12.8							12.8
Calaveras.....	600								- 45
Colusa.....	1,169	11			556			567	48.5
Contra Costa.....	635	5.4	300	30				335.4	52.78
Del Norte.....	120								- 42.5
El Dorado.....	900	6		6				12	1.33
Fresno.....	3,800	27	14	1			1,080	1,122	29.52
Glenn.....	1,368	27.5		.5	395			423	30.92
Humboldt.....	1,348		15		310	110		435	32.27
Imperial.....	590	11.7				6		17.7	3
Inyo.....	923								17.7

¹ Concrete mileage reported by State geologist, balance 1909 figures.

CALIFORNIA—Continued.

TABLE 8.—Mileage of public roads outside of incorporated cities and towns, 1914—Con.

County.	Total mileage of all roads.	Surfaced roads.								Graded and drained earth.	
		Concrete.	Macadam.	Bituminous macadam.	Gravel.	Sand-clay.	Oiled earth.	Total of surfaced roads.	Percentage of roads surfaced.		Increase in surfaced mileage over 1909.
Kern.....	1,400	61.8					500	561.8	40.12	459.8	200
Kings ¹	500	9					92	101	20.2	9	
Lake.....	700				50			50	7.14	110	150
Lassen.....	1,700									50	700
Los Angeles.....	3,500	50.8		409				459.8	13.13	625.2	
Madera.....	1,250	17.1		34			7	58.1	4.64	28.1	940
Marin ²	309										
Mariposa.....	460										
Mendocino.....	800	4		7.7				11.7	1.46	11.7	50
Merced.....	1,218	37			20	261.25		318.25	26.12	181.25	600
Modoc.....	650									10	300
Mono.....	425										
Monterey.....	1,090	20.7	50					70.7	6.48	29.3	467
Napa ¹	560	6.5	3		450			459.5	82.05	6.5	
Nevada.....	800		25					25	3.12	5	150
Orange.....	615	97		5			350	452	73.49	422	50
Placer.....	1,200	10.1	5					15.1	1.25	8.1	50
Plumas ²	385				10			10	2.59		
Riverside.....	1,714	10.3		8				18.3	1.06	35.7	112
Sacramento.....	1,636	29.7	7	82.97	10		50	173.37	10.59	67.37	500
San Benito.....	468	4.7	8	6.9	50	140		209.6	44.78	100.4	160
San Bernardino.....	700	75		50	200		300	625	89.28	625	
San Diego.....	5,000	42.8		2.3				45.1	.9	404.9	1,743
San Joaquin.....	1,350			34				34	2.51	3	294
San Luis Obispo.....	1,353	39.9					3	42.9	3.08	120.1	750
San Mateo.....	284	40	23	32			25	120	42.25	108	134
Santa Barbara.....	1,143	21.7		17			22.40	61.1	5.34	4.9	23.75
Santa Clara.....	675	45.1	250	42	92			429.1	63.57	396.9	75
Santa Cruz.....	450		10	3	50			63	14	12.75	291
Shasta.....	1,800				65			65	3.61	171	26.4
Sierra.....	379		5					5	1.31	5	50
Siskiyou.....	1,300		16.5		66			82.5	6.34	58	626
Solano.....	700	34.2	5	10			40	89.2	12.74	54.2	100
Sonoma.....	1,420	20.2						20.2	1.41	724.8	1,400
Stanislaus.....	1,200	21.7		40	40			101.7	8.47	46.7	920
Sutter.....	375	12		15	65	40		132	35.2	74	100
Tehama.....	750	9	7		100			116	15.46	50	600
Trinity.....	400									5	248
Tulare.....	3,600	13.7					1,000	1,013.7	28.15	953.7	1,600
Tuolumne.....	860						20	20	23.25	47	740
Ventura.....	554	31.6		3				34.6	6.25	65.4	24.5
Yolo.....	800	25	15.5	15	419.5	25		500	62.5	107.5	200
Yuba.....	600	3.4	14	9.2				26.6	4.43	11.6	10
Total.....	61,039	929.19	837.4	877.9	3,563.59	582.25	3,489.40	10,279.73	16.84	1,691.98	18,389.3

¹ Concrete mileage reported by State geologist, balance 1909 figures.² No report; 1909 mileage.

COLORADO.

TABLE 9.—*Mileage of public roads outside of incorporated cities and towns, 1914.*

County.	Total mileage of all roads.	Surfaced roads.						Graded and drained earth.
		Gravel.	Sand-clay.	Other hard-surfaced roads.	Total of surfaced roads.	Percentage of roads surfaced.	Increase in surfaced mileage over 1909.	
Adams.....	673	40		4	44	6.53	— 8	320
Alamosa.....	564	3			3	.53	3	62
Arapahoe.....	378	24.5			24.5	5.48	8.5	100
Archuleta.....	208	4			4	1.92	4	204
Baca.....	117							63
Bent.....	506			6	6	1.18		400
Boulder.....	620	67	40		107	17.26	67	513
Chaffee.....	325	40	25		65	20	65	20
Cheyenne.....	164							164
Clear Creek.....	110							45
Conejos.....	327	2	25		27	8.25	27	140
Costilla.....	126						— 8	33
Crowley.....	346							175
Custer.....	351			17	17	4.84	17	
Delta.....	875.5							162
Denver ¹								
Dolores.....	100							8
Douglas.....	576			13	13	2.25	13	
Eagle.....	270							110
Elbert.....	1,700							200
El Paso.....	2,000	75		35	110	5.5	80	1,443
Fremont.....	460						— 2	340
Garfield.....	510	10			10	1.98	8	100
Gilpin.....	124							25
Grand.....	386			5	5	1.29	5	
Gunnison.....	573							238
Hinsdale.....	225							75
Huerfano.....	575							175
Jackson.....	305							111
Jefferson.....	634	75	10	² 1	86	13.56	71	369
Kiowa.....	200		25		25	12.5	25	
Kit Carson.....	1,076							70
Lake.....	165		50		50	30.3	46	15
La Plata.....	1,000			³ 1	1	.1	1	299
Larimer.....	1,500	60		⁴ 2.25	62.25	4.15	62.25	937.75
Las Animas.....	1,000							100
Lincoln.....	600							300
Logan.....	1,042			15	15	1.43	8.5	
Mesa.....	2,200							300
Mineral.....	98							98
Moffat.....	550							97
Montezuma.....	500							
Montrose.....	1,008.6							534.6
Morgan.....	1,000	16			16	1.6	16	600
Otero.....	775	10	15		25	3.22	5	600
Ouray.....	202	3			3	1.48	3	199
Park.....	376	6			6	1.59	6	150
Phillips.....	314		5		5	1.59	5	31
Pitkin.....	193			6	6	3.1	6	38
Prowers.....	769		8.25	1.25	9.5	1.23	4.5	90.5
Pueblo.....	1,890	17	1	42	60	3.17	48	75
Rio Blanco.....	400							40
Rio Grande.....	350		100		100	28.57	62	
Routt.....	456			3	3	.65	3	
Saguache.....	1,575		75		75	4.76	75	300
San Juan.....	125							125
San Miguel.....	318.87	6	32.87		38.87	12.19	38.87	21
Sedgwick.....	165	3.75			3.75	2.27	— .25	32
Summit.....	214							100
Teller.....	186	12		17	29	15.59	29	157
Washington.....	1,760		20		20	1.29	20	200
Weld.....	3,101	100		³ 1	101	3.25	41	1,000
Yuma.....	542		18		18	3.32	18	
Total.....	39,779.97	574.25	450.12	169.50	1,193.87	3	873.37	12,104.85

¹ All within city limits.² Concrete.³ Plain macadam.⁴ Concrete, 1.25 miles; plain macadam, 1 mile.

IDAHO.

TABLE 10.—Mileage of public roads outside of incorporated cities and towns, 1914.

County.	Total mileage of all roads.	Surfaced roads.						Increase in surfaced mileage over 1909.	Graded and drained earth.
		Macadam.	Gravel.	Sand-clay.	Other hard surfaced roads.	Total of surfaced roads.	Percentage of roads surfaced.		
Ada.....	620	.....	57	5	18	70	11.29	63	.....
Bannock.....	600	.....	26	.....	.....	26	4.33	26	.....
Bear Lake.....	500	.....	5	.....	.....	5	1	—	30
Bingham.....	600	7	.....	20	.....	27	4.5	27	150
Blaine.....	800	.....	10	45	.....	55	6.87	55	60
Boise.....	1,000	.....	2	.....	.....	2	.2	2	.....
Bonner.....	519	.....	5	.....	.....	5	.96	5	219
Bonneville.....	525	.....	.....	.....	.....	.....	.....	.....	175
Canyon.....	500	.....	10	20	.....	30	6	.....	48
Cassia.....	600	.....	10	.....	.....	10	1.66	10	48
Clearwater.....	400	.....	.....	.....	.....	.....	.....	.....	150
Custer.....	355	.....	.....	.....	.....	.....	.....	.....	15
Elmore.....	500	.....	.....	18	.....	18	3.6	18	275
Franklin.....	265	.....	10	.....	.....	10	3.77	10	62
Fremont.....	500	.....	.....	.....	23	3	.6	3	90
Gooding.....	350	.....	.....	.....	.....	.....	.....	.....	100
Idaho.....	1,400	.....	.....	.....	.....	.....	.....	— 11.5	1,000
Jefferson.....	300	.....	.....	75	.....	75	25	75	.....
Kootenai.....	350	.....	.....	.....	.....	.....	.....	—150	150
Latah.....	1,100	2.5	2	12	.....	16.5	1.5	1.5	.....
Lemhi.....	850	.....	.....	.....	.....	.....	.....	.....	50
Lewis.....	500	.....	.....	.....	.....	.....	.....	.....	200
Lincoln.....	874	.....	4	123	.....	127	14.53	127	425
Madison.....	300	.....	25	.....	.....	25	8.33	25	275
Minidoka.....	1,455	.....	.....	5	.....	5	.34	5	150
Nez Perce.....	825	8	.....	.....	88.5	16.5	2	14.5	300
Oneida.....	400	.....	.....	100	.....	100	25	90	100
Owyhee.....	800	.....	.....	20	.....	20	2.5	.....	.....
Power.....	556	.....	.....	6	.....	6	1.07	6	150
Shoshone.....	325	25	.....	.....	.....	25	7.69	—205	.....
Twin Falls.....	5,077	.....	2	.....	.....	2	.03	2	75
Washington.....	650	.....	.....	.....	.....	.....	.....	.....	150
Total.....	24,396	42.5	168	449	19.5	679	2.78	168.5	4,399

¹ 3.5 miles macadam with bitumen; 4.5 miles concrete.² Cinders.³ Bituminous macadam.

ILLINOIS.

TABLE 11.—*Mileage of public roads outside of incorporated cities and towns, 1914.*

County.	Total mileage of all roads.	Surfaced roads. ¹									Graded and drained earth.	
		Brick.	Concrete.	Bituminous macadam.	Macadam.	Gravel.	Sand-clay.	Other hard-surfaced roads.	Total of surfaced roads.	Percentage of roads surfaced.		Increase in surfaced mileage over 1909.
Adams.....	1,562		2		20	79	65	5	171	10.94	— 6	
Alexander.....	244			2		37		1	40	16.39	20	102
Bond.....	676	1.5	1.5		7				10	1.47	3	440
Boone.....	512		1		45	179.5	15		240.5	46.97	— 8.5	146
Brown.....	550						200		200	36.36	199	100
Bureau.....	1,415		4		2	551			557	39.36	66	300
Calhoun.....	355						100		100	28.16	98	100
Carroll.....	759				34	11	2		47	6.19	1	313
Cass.....	705			2.5			34.5	35	72	10.21	72	200
Champaign.....	2,000	4.5							4.5	.22	.5	1,806
Christian.....	1,295	3							3	.23	14	1,176
Clark.....	1,000		1		63	39	35		138	13.8	90	479
Clay.....	847		1						1	.11	1	107
Clinton.....	768				2				2	.26	2	703
Coles.....	1,069	3.12	.25	7.25	15.75	86.25	403		515.62	48.23	489.62	553.38
Cook.....	1,143		18.3	.2	125.58	164.85			308.93	27.02	— 509.07	100.72
Crawford.....	801	6	4.5	3	69.5	42.2	25		150.2	18.75	125.2	287
Cumberland.....	704										— 5	250
Dekalb.....	1,094		5.6	19.25	11.5	463.8			500.15	45.71	85.15	272.90
Dewitt.....	726											313
Douglas.....	800	5.75	2		27.5				35.25	4.4	35.25	280
Dupage.....	552		2.5	3	45	359.5			410	74.27	— 20	142
Edgar.....	923	13			52	255			320	34.66	85	399
Edwardsville.....	446					1.3			1.3	.29	1.3	294
Effingham.....	1,052		1.5		4	1			6.5	.61	1.5	1,066.75
Fayette.....	1,400		1.87		3				4.87	.34	.87	182
Ford.....	924	1.12			1	98.5			100.62	10.88	5.62	731.2
Franklin.....	716.5										— 6	
Fulton.....	1,494	9					108		117	7.83	116	1,125
Gallatin.....	400										— 2	
Greene.....	853.75			.5	.5		4		5	.58	—	336
Grundy.....	739		1.75		35.5	63			100.25	13.56	2.25	
Hamilton.....	900											100
Hancock.....	1,381			2	47	111	334		494	35.77	470	680
Hardin.....	193											20
Henderson.....	620					1	16		17	2.74	17	211
Henry.....	1,379			2		3			5	.36	— 3	1,171
Iroquois.....	2,119		6.75	3	37.5	44			91.25	4.3	11.25	1,551.5
Jackson.....	729	.75		10	6.25	2			19	2.6	11	403
Jasper.....	900											400
Jefferson.....	70		1						1	1.42	1	29
Jersey.....	528.38			1.25	1.12				2.37	.44	— 2.63	526.01
Jo Daviess.....	914	.09	14.8		8.15		2		25.04	2.73	— 26.96	121.1
Johnson.....	450											137
Kane.....	835.73	.2	5.85	1.5	21.05	638.98		33.7	671.28	80.32	— 128.72	68.25
Kankakee.....	1,458		1.75		158.75	10.5	289.5		460.5	31.58	303.5	741.75
Kendall.....	529				11.5	251.77			263.27	49.76	— 7.73	203.1
Knox.....	1,318	.25				1			1.25	.09	— 1.75	548
Lake.....	728		3	1.5	40	292			336.5	46.22	25.5	275
La Salle.....	2,018	1.5	3		40	560	75		679.5	33.67	166.5	134.1
Lawrence.....	687		4.62		25	35			64.62	9.4	37.62	141
Lee.....	1,255	.06	2.4	7	153	53	2	3	220.46	17.56	68.46	500
Livingston.....	2,016		2.5	1.5	22	53			79	3.91	2	1,874
Logan.....	927.75		3.25	3	2	6.5	8		22.75	2.45	16.75	844.75
McDonough.....	1,147				1.5				1.5	.13	.5	527
McHenry.....	1,002		2.75			900			902.75	90.09	122.75	99.25
McLean.....	2,115		2.5		13.5	44			60	2.83	— 56	1,000
Macon.....	1,025					68			68	6.63		
Macoupin.....	1,451.5	.5	3						3.5	.24	3.5	800
Madison.....	1,500	2.25	10.75	4	16.75			3	36.75	2.45	— 9.25	750
Marion.....	1,173		1		.5				1.5	.12	.5	131
Marshall.....	604					46	116.75		162.75	26.94	112.75	441.25
Mason.....	760											489
Massac.....	411					47			47	11.43	— 2	364

¹ Includes all classifications of surfaced roads; 1909 report included stone and gravel only.² Oiled roads.³ Cinders.⁴ 1909 mileage report.

ILLINOIS—Continued.

TABLE 11.—*Mileage of public roads outside of incorporated cities and towns, 1914—Con.*

County.	Total mileage of all roads.	Surfaced roads. ¹								Graded and drained earth.		
		Brick.	Concrete.	Bituminous macadam.	Macadam.	Gravel.	Sand-clay.	Other hard-surfaced roads.	Total of surfaced roads.		Percentage of roads surfaced.	Increase in surfaced mileage over 1909.
Menard.....	411		0.5						0.5	0.12	0.5	
Mercer.....	953						55		55	5.77	55	493
Monroe.....	530				35		86		121	22.83	100	409
Montgomery..	1,250				2.5				2.5	.2	2.5	
Morgan.....	1,001.33		1.33	15					16.33	1.63	16.33	489
Moultrie.....	683.5			1	5		121		122.5	17.92	122.5	558
Ogle.....	1,337	2		4	175	76.75			257.75	19.27	62.75	711
Peoria.....	1,138.85		2.25	2		123.5			127.75	11.21	98.25	265.55
Perry.....	700											350
Piatt.....	737.5	1							1	.13	1	600
Pike.....	1,541		1.57		6	26	308.2		341.77	22.17	290.77	
Pope.....	510										7	278
Pulaski.....	295					43			43	14.57	39	142
Putnam.....	310					60			60	19.35	23	200
Randolph.....	809		.5		5				5.5	6.8	19.5	75
Richland.....	257						32		32	12.45	31	100
Rock Island..	630		1.25						1.25	.19	31.75	
St. Clair.....	1,020				31				31	3.03	2	
Saline.....	585	7	1		.75				8.75	1.49	6.75	
Sangamon.....	1,500	.41	4.15	.83	.33				5.72	.38	2.72	1,200
Schuyler.....	772		1.28						1.28	.16	2.72	236
Scott.....	450											375
Shelby.....	1,500		1.21						1.21	.08	.21	500
Stark.....	570										2	290
Stephenson..	1,090	.62	.5		16	44	4	*5	70.12	6.43	32.88	285
Tazewell.....	1,071		3		.5	68			71.5	6.67	18.5	841.5
Union.....	642				.5	49			49.5	7.71	24.5	280
Vermilion....	1,560	10			8	168			186	11.92	21	
Wabash.....	500					24			24	4.8	24	
Warren.....	1,010	7			3.75	7.5			18.25	1.8	8.25	575
Washington..	842										2	218
Wayne.....	1,427											903
White.....	868.75				9	22			31	3.56	23	752.25
Whiteside....	1,139.5	2.3	2.85		44.5	170.4	27		247.05	21.68	47.05	391
Will.....	1,809.5		4.5	17.75	163.75	399		*2	587	32.43	177	1,200
Williamson..	644.75		1.19	1.5	1.25				3.94	.61	3.94	
Winnebago...	931		2.78	5	2.38	157.5			167.66	18	235.34	50
Woodford....	960		1.25			14			15.25	1.58	3.25	850
Total.....	95,647.29	82.92	148.8	121.53	1,675.11	7,052.3	2,467.95	57.7	11,606.31	12.02	2,692.31	41,143.31

¹ Includes all classifications of surfaced roads; 1909 report included stone and gravel only.² Oiled roads.³ Shale.

INDIANA.

TABLE 12.—Mileage of public roads outside of incorporated cities and towns, 1914.

County.	Total mileage of all roads.	Surfaced roads.							Graded and drained earth.	
		Concrete.	Bituminous macadam.	Macadam.	Gravel.	Other hard-surfaced roads.	Total of surfaced roads.	Percentage of roads surfaced.		Increase in surfaced mileage over 1909.
Adams.....	774			390	112		502	64.8	247	272
Allen.....	900	8	7	290	100		405	45	—286.5	295
Bartholomew.....	955			65	385		450	47.1	85	200
Benton.....	900			150	260		410	45.5	154.5	490
Blackford.....	470	.5		85	180	19	275.5	58.6	175.5	.....
Boone.....	816	2		555			557	68.2	—178.5	200
Brown.....	350				33		33	9.4	23	50
Carroll.....	1,045		3	42	350		395	37.8	80	617
Cass.....	1,302			200	252		452	34.7	74.5	.....
Clark.....	694.5			184.5	33		217.5	31.3	121.5	477
Clay.....	626		3	75	268		346	55.2	33.25	200
Clinton.....	940			20.93	739.23		760.16	80.8	260.16	179.84
Crawford.....	420			70			70	16.6	44	50
Daviess.....	860			100	200		300	34.8	136	300
Dearborn.....	435		3.14	75	7		85.14	19.5	—45.11	150
Decatur.....	600			345.75			345.75	57.6	161.75	150
Dekalb.....	900			6	21		27	3	—252	173
Delaware.....	820		2	62.75	351.75	114	430.50	51.8	—195	270.50
Dubois.....	750			85			85	11.3	36.5	400
Elkhart.....	550	6	7		12	14	29	5.2	—266	.....
Fayette.....	400	.3		10	270		280.3	70.07	9.55	60
Floyd.....	299.25		17.75	26	3.5		47.25	15.7	—71.75	252
Fountain.....	1,200		2.62	54	265		321.62	26.8	—52.38	450
Franklin.....	1,000				178.5		178.5	17.85	61.5	.....
Fulton.....	682				85		85	12.4	—8.5	282
Gibson.....	1,350			242	31		273	20.2	148	500
Grant.....	936		60	200	573	13	836	89.3	380.5	.....
Greene.....	953	1.5			453		454.5	47.6	172.75	.....
Hamilton.....	1,000	1			700		701	70.1	301	300
Hancock.....	700			40	500		540	77.1	114	160
Harrison.....	1,053			133	10		143	13.5	73.5	.....
Hendricks.....	900			100	230		330	36.6	—23.5	100
Henry.....	730	1.25		1.5	450		452.75	62.02	—106.25	150
Howard.....	616			20	497		517	83.9	230	.....
Huntington.....	888.5	1.25		50	324.25		375.5	42.2	—86.5	413
Jackson.....	812	.5		29.5	547		577	71.05	57.5	.....
Jasper.....	810			175	35		210	25.9	—3.25	.....
Jay.....	664			80	356		436	65.6	55	.....
Jefferson.....	796.65			191.65	5		196.65	24.6	—1.85	.....
Jennings.....	651			251			251	38.5	7	100
Johnson.....	792			5	295		300	37.8	145	484
Knox.....	1,181	1			600		601	55.5	206.5	.....
Kosciusko.....	1,300				16		16	1.2	—338.75	.....
Lagrange.....	826								—130	799
Lake.....	1,050	1	28	376	45		450	42.8	334.5	600
Laporte.....	1,200		1	258.77	2.73		262.5	21.8	152	760
Lawrence.....	828			304.5	168.75		473.25	57.1	145.75	.....
Madison.....	900	4.5			800		804.5	89.3	382.5	.....
Marion.....	881			433			433	49.1	—92	400
Marshall.....	882.5		3.5	20.5	58.5		82.5	9.3	—83	.....
Martin.....	370			100			100	27.02	64	70
Miami.....	970.2			6.45	338.75		345.2	35.5	25.2	625
Monroe.....	865			326			326	37.6	115	300
Montgomery.....	850	1.5	17.5	30	451		500	58.8	—117.75	.....
Morgan.....	675			75	199	11	274	40.59	23.5	200
Newton.....	690			302			302	43.7	147	.....
Noble.....	850				600		600	70.5	380	200
Ohio.....	227			42			42	18.5	—23	.....
Orange.....	700			225	75		300	42.8	58.5	200
Owen.....	596			190	48		238	39.9	—332	.....
Parke.....	773				698.1		698.1	90.3	120.1	431.5
Perry.....	800			18.5			18.5	2.3	18.5	200
Pike.....	800			76	4		80	10	44	200
Porter.....	1,000			273.41			273.41	27.34	109.16	500.31
Posey.....	662			40	172		212	32.02	63.75	400

1 Brick.

INDIANA—Continued.

TABLE 12.—Mileage of public roads outside of incorporated cities and towns, 1914—Continued.

County.	Total mileage of all roads.	Surfaced roads.							Graded and drained earth.	
		Concrete.	Bituminous macadam.	Macadam.	Gravel.	Other hard-surfaced roads.	Total of surfaced roads.	Percentage of roads surfaced.		Increase in surfaced mileage over 1909.
Pulaski.....	864			25	292.5		317.5	36.7	224.75	546.5
Putnam.....	1,200		4	425	421		850	70.8	282	
Randolph.....	1,070		2	2	520		524	48.9	17.5	400
Ripley.....	442			291	11		302	68.09	160	140
Rush.....	975		2.5	50	337.5		390	40	91	225
St. Joseph.....	499	12.5		3	37.5	2140	193	38.7	77	75
Scott.....	300.6	.6		50	100		150.6	50.09	100.1	100
Shelby.....	837	.5		30	285		315.5	37.6	38.5	197
Spencer.....	951			48.3	3		51.3	5.3	21.3	300
Starke.....	650			13.5	289.5		303	46.6	180	428
Steuben.....	960			25			25	2.6	15	
Sullivan.....	974		.09	170	300		470.09	48.2	87.09	
Switzerland.....	448			128	20	210	158	35.3	36	200
Tippecanoe.....	1,033		3	10	570.39		583.39	56.4	161.14	200
Tipton.....	656		1.25	50	598.75		650	99.08	228	6.75
Union.....	280			5	115		120	42.8	10	100
Vanderburg.....	722	1		183	17	{ 2.25 1.75 }	202	27.9	50	520
Vermilion.....	800	3		2.5	400.5	11	407	50.8	149.5	
Vigo.....	886	2		398		12	402	45.3	83	
Wabash.....	852			109	316		425	49.8	97	427
Warren.....	610			2.83	373.89		376.72	61.7	73.72	165.38
Warrick.....	470			70			70	14.8	40	
Washington.....	1,475			225			225	15.2	395	
Wayne.....	753	3.27		10.45	710		723.72	96.1	581.72	
Wells.....	808			254	486		740	91.5	189	68
White.....	970			200	170		370	38.1	100	
Whitley.....	634			3	501		504	79.4	254	
Total.....	73,347.20	53.17	168.35	10,291.29	20,264.59	3187	30,962.40	42.2	6,006.65	17,509.78

¹ Brick.² Sand-clay.³ Comprising 34.75 miles brick and 150.25 miles sand clay.

IOWA.

TABLE 13.—Mileage of public roads outside of incorporated cities and towns, 1914.

County.	Total mileage of all roads.	Surfaced roads.						Increase in surfaced mileage over 1909.
		Macadam.	Gravel.	Sand-clay.	Concrete.	Total of surfaced roads.	Percentage of roads surfaced.	
Adair.....	1,162							
Adams.....	845							
Allamakee.....	1,052	2				2	.19	— 3.5
Appanoose.....	1,276							
Audubon.....	909							
Benton.....	1,450	3		1	.8	2.1	.14	— 11.9
Black Hawk.....	1,216	2				2	.16	— 52.5
Boone.....	1,068		2			2	.18	— 69.75
Bremer.....	923	3				3	.32	— 90.75
Buchanan.....	1,122		12			12	1.06	— 90.25
Buena Vista.....	1,182		10			10	.84	— 42.5
Butler.....	1,177							— 95
Calhoun.....	1,195		10			10	.83	— 30
Carroll.....	1,210		20			20	1.65	— 56
Cass.....	1,116							
Cedar.....	1,073							— .5
Cerro Gordo.....	1,212		5		2	7	.57	— 17.5
Cherokee.....	1,198		12			12	1.001	— 8
Chickasaw.....	1,002			2		2	.19	— 65
Clarke.....	757							
Clay.....	1,145							— 24
Clayton.....	1,438	3				3	.208	— 71.5
Clinton.....	1,317	10	10.5		.1	20.6	1.56	— 41.65
Crawford.....	1,390		5			5	.35	4.75
Dallas.....	1,123		8			8	.71	— 4
Davis.....	1,021							
Decatur.....	985							
Delaware.....	1,139	7	20	6		33	2.89	— 6
Des Moines.....	806				1	1	.12	— 52
Dickinson.....	681		10			10	1.46	— 30
Dubuque.....	1,076	10	25			35	3.25	— 59.85
Emmet.....	736		16			16	2.17	14.5
Fayette.....	1,412			7		7	.49	— 70.5
Floyd.....	1,060							— 55
Franklin.....	1,213							— 37
Fremont.....	925							
Greene.....	1,921		30			30	2.93	— 121.5
Grundy.....	1,003							
Guthrie.....	1,346		6			6	.44	— 7.5
Hamilton.....	1,149		10			10	.87	— 15
Hancock.....	1,027							— 114.5
Hardin.....	1,183		3			3	.25	— 105.5
Harrison.....	1,211							— 4
Henry.....	848							
Howard.....	851							— 31.5
Humboldt.....	841		11			11	1.3	— 21
Ida.....	888							
Iowa.....	1,212		4	2		6	.49	— 11.5
Jackson.....	1,242							— 12.5
Jasper.....	1,490							— 17
Jefferson.....	890							— 3
Johnson.....	1,073							— 8.75
Jones.....	1,193							— 10
Keokuk.....	1,232	8				8	.64	— 102
Kossuth.....	1,905		5			5	.26	— 5
Lee.....	1,042	17	2			19	1.81	4
Linn.....	1,550	25	22	5		52	3.35	17.5
Louisa.....	714				1.37	1.37	.19	1.37
Lucas.....	875							
Lyon.....	1,291							
Madison.....	1,198							
Mahaska.....	1,140							— 3
Marion.....	1,155							
Marshall.....	1,275		2			2	.15	1
Mills.....	824							
Mitchell.....	924		20			20	2.16	13
Monona.....	1,268							— .5
Monroe.....	1,048							
Montgomery.....	843							
Muscatine.....	899		11		.5	11.5	1.27	— 37
O'Brien.....	1,204							— 4.5

IOWA—Continued.

TABLE 13.—*Mileage of public roads outside of incorporated cities and towns, 1914—Contd.*

County.	Total mileage of all roads.	Surfaced roads.						Increase in surfaced mileage over 1909.
		Mac- adam.	Gravel.	Sand- clay.	Con- crete.	Total of sur- faced roads.	Percent- age of roads surfaced.	
Osceola.....	856		6			6	.7	2
Page.....	1,158							
Palo Alto.....	1,018		5			5	.49	2.75
Plymouth.....	1,625							
Pocahontas.....	1,240		8			8	.64	6
Polk.....	1,652		10			10	.605	9.5
Pottawattamie.....	1,950							10
Poweshiek.....	1,202							
Ringgold.....	1,219							
Sac.....	1,187		25			25	2.1	14.5
Scott.....	1,061	80	5			85	8.01	29.75
Shelby.....	1,142							
Sioux.....	1,594							10
Story.....	1,201		50			50	4.16	76
Tama.....	1,407							9.25
Taylor.....	1,194							
Union.....	974							
Van Buren.....	933							
Wapello.....	965							7
Warren.....	1,210							
Washington.....	1,147							
Wayne.....	1,119							
Webster.....	1,351							29
Winebago.....	864		4			4	.45	57.5
Winnesheik.....	1,354	4				4	.29	24
Woodbury.....	1,470		10			10	.68	9.5
Worth.....	742							36.5
Wright.....	1,194							22.5
Total.....	112,496							
City streets.....	8,422							
Country roads.....	104,074	171.3	414.5	23	5.77	614.57	.59	-1,890.53

¹ Includes 1.5 miles of shell, of which 0.5 of a mile is in Clinton County and 1 mile in Muscatine County.

KANSAS.

TABLE 14.—*Mileage of public roads outside of incorporated cities and towns, 1914.*

County.	Total mileage of all roads.	Surfaced roads.						
		Ma- cadam.	Gravel.	Sand- clay.	Other hard- surfaced roads.	Total of surfaced roads.	Percent- age of roads surfaced.	Increase in sur- faced mileage over 1909.
Allen.....	800	33			¹ 75	33.75	4.21	22.75
Anderson.....	1,125	1	.5		² 2	3.5	.31	2.5
Atchison.....	810	5			³ 5	5.5	.67	-4.5
Barber.....	900							
Barton.....	1,225				³ 10	10	.81	10
Bourbon.....	1,332	35				35	2.62	10.25
Brown.....	700							
Butler.....	2,377							
Chase.....	1,100							
Chautauqua.....	1,000		2			2	.2	2
Cherokee.....	960		60			60	6.25	40
Cheyenne.....	600			20		20	3.33	19.5
Clark.....	658			10		10	1.51	3
Clay.....	1,337			2		2	.14	2
Cloud.....	1,360			1		1	.07	1
Coffey.....	1,296		3		⁴ 1.5	4.5	.34	4.5
Comanche.....	637							-2
Cowley.....	1,925							- .75
Crawford.....	1,150		4			4	.33	4
Decatur.....	1,464							
Dickinson.....	1,656		3	10		13	.78	1
Doniphan.....	707	1.5				1.5	.21	0
Douglas.....	1,000	4				4	.4	0
Edwards.....	878			71		71	8.08	31
Elk.....	1,000	1	3			4	.4	-27
Ellis.....	1,114							
Ellsworth.....	942							
Finney.....	875			8	⁴ 2	10	1.14	1
Ford.....	1,507			9		9	.59	4
Franklin.....	1,152	.25	2			2.25	.19	.8
Geary.....	500	5				5	1	2.5
Gove.....	234							
Graham.....	1,309							
Grant.....	1,200			25		25	2.08	25
Gray.....	600			10		10	1.66	0
Greeley.....	225							
Greenwood.....	1,843							
Hamilton.....	125			5.5		5.5	4.4	0
Harper.....	614			20		20	3.24	20
Harvey.....	1,128			12		12	1.06	12
Haskell.....	500							
Hodgeman.....	500							
Jackson.....	1,196							
Jefferson.....	1,100	.5	.75			1.25	.11	1.25
Jewell.....	1,766							
Johnson.....	1,015	22			⁴ 3	25	2.46	20
Kearny.....	478			5		5	1.04	5
Kingman.....	1,612			60		60	3.72	59.25
Kiowa.....	739							
Labette.....	600							-1
Lane.....	263							
Leavenworth.....	850	2			³ 3	5	.59	0
Lincoln.....	960		5			5	.52	5
Linn.....	920							
Logan.....	357							
Lyon.....	1,760	5	5			10	.56	3
McPherson.....	1,653							
Marion.....	1,986							
Marshall.....	1,685							
Meade.....	599							
Miami.....	1,210							
Mitchell.....	1,320							
Montgomery.....	1,200							
Morris.....	800							
Morton.....	150			9		9	6	9
Nemaha.....	1,455							
Neosho.....	1,160	6				6	.56	.95
Ness.....	455							
Norton.....	1,531			.25	² 5	5.25	.34	5.25

¹ Concrete.² Shale.³ Brick.⁴ Oiled earth.

KANSAS—Continued.

TABLE 14.—*Mileage of public roads outside of incorporated cities and towns, 1914—Contd.*

County.	Total mileage of all roads.	Surfaced roads.						Increase in surfaced mileage over 1909.
		Macadam.	Gravel.	Sand-clay.	Other hard-surfaced roads.	Total of surfaced roads.	Percentage of roads surfaced.	
Osage.....	1,368							
Osborne.....	1,650	5				5	0.303	5
Ottawa.....	1,304			50		50	3.83	50
Pawnee.....	1,424			10		10	.7	-15
Phillips.....	1,823							
Pottawatomie.....	1,600	6	12			18	1.12	-21
Pratt.....	1,000							
Rawlins.....	270							
Reno.....	2,404			125		125	5.19	120
Republic.....	700			2		2	.28	5
Rice.....	1,350			100	¹ 2	102	7.55	102
Riley.....	1,100		.6	1.25	² .6	2.45	.22	2.45
Rooks.....	1,608			2		2	.12	2
Rush.....	1,358							
Russell.....	1,350							
Saline.....	1,525				¹ 2.6	2.6	.17	2.6
Scott.....	290							
Sedgwick.....	2,390		1	31	¹ 5	37	1.54	37
Seward.....	296			9		9	3.04	3
Shawnee.....	1,096	5.75	46.5		(³)	57.5	5.24	57.5
Sheridan.....	1,400				5.25			
Sherman.....	180							
Smith.....	1,820							
Stafford.....	1,500			150		150	10	134
Stanton.....	303							
Stevens.....	230							
Sumner.....	1,115							
Thomas.....	137							
Trego.....	1,000							
Wabaunsee.....	1,500	1	.5	.5		2	.13	.5
Wallace.....	98							
Washington.....	1,800							
Wichita.....	608							
Wilson.....	1,000		3			3	.3	3
Woodson.....	1,004							
Wyandotte.....	266	55.3			¹ 1	56.3	21.16	- 1.7
	111,052	194.3	151.85	758.5	44.2	1,148.85	1.03	774.14

¹ Oiled earth.² Concrete.³ Cinders, 1.25; brick, 0.6; oiled earth, 3.4.

MICHIGAN.

TABLE 15.—*Mileage of public roads outside of incorporated cities and towns, 1914.*

County.	Total mileage of all roads.	Surfaced roads.							Graded and drained earth.	
		Con- crete.	Bitu- minous mac- adam.	Mac- adam.	Gravel.	Sand- clay.	Total of sur- faced roads.	Per- centage of roads sur- faced.		In- crease in sur- faced mileage over 1909.
Alcona.....	485.85				4	35	39	8.01	14	4
Alger.....	332			11.05	44	19	74.05	22.3	39.32	29
Allegan.....	1,767.2			4.61	81.05	27	112.66	6.37	250.34	
Alpena.....	591.3			110	48	15	173	29.26	22.5	36
Antrim.....	832.5			5.29	88.2	14	107.49	12.9	54.16	
Arenac.....	601.4				22.03	12	34.03	5.65	29.03	60
Baraga.....	383.6				10	65	75	19.55	7.75	
Barry.....	1,141.1				240.9	150	390.9	34.25	361.9	
Bay.....	972.2	2.16	10	151.2	14.2	25	202.56	20.83	29.56	35
Benzie.....	560.2			.75	110.5	1.5	112.75	20.12	75	
Berrien.....	1,198.1	.89	30	35.43	81.14	.25	147.71	12.32	1.04	
Branch.....	926.6			1	60.25	30	91.25	9.84	70.5	50
Calhoun.....	1,233.5		2	11.25	130.5	11	154.75	12.54	140.9	25
Cass.....	964.3				74.56	16	90.56	9.39	40.89	14
Charlevoix.....	663		2	8.8	46.5	20	77.3	11.65	3.3	36
Cheboygan.....	814.6			15.16	30.2	68	113.36	13.91	15.86	17
Chippewa.....	218.6			4	93	60	157	71.82	136.75	40
Clare.....	811				37.75	1	38.75	4.77	33.5	7
Clinton.....	1,206				62.37	6.5	68.87	5.71	3.37	16
Crawford.....	480.3			1	26.23	4.98	32.21	6.7	24.71	
Delta.....	820.1			52.22	88	10	150.22	18.31	26.97	30
Dickinson.....	416		2	15.57	11	56	84.57	20.32	25.21	14
Eaton.....	1,140.9				115	20	135	11.83	95	44
Emmet.....	702.3			12.25	30.56	24	66.81	9.51	22.81	13
Genesee.....	1,297.8			23.5	181.46	7.68	212.64	16.38	156.64	29
Gladwin.....	604.1				20	10	30	4.96	6.5	40
Gogebic.....	254.5			3.06	13.57	65	81.63	32.07	6.63	50
Grand Traverse.....	780.6		1	.81	67	5.92	74.73	9.57	22.48	5
Gratiot.....	1,299.7				172.46	22.18	194.64	14.97	10.14	70
Hillsdale.....	1,211.9		1	9.73	48.02	16	74.75	6.16	13.75	8
Houghton.....	279.5		6	18.21	43.11	18	85.32	30.52	23.18	7
Huron.....	1,670.5	2.07	.5	33.68	83.79	3.69	123.73	7.4	104.93	40
Ingham.....	1,167.5			2	50.36	.5	52.86	4.52	20.47	13
Ionia.....	1,243.2				116.27	15	131.27	10.55	53.52	14
Iosco.....	512.4			5.36	10.5	5.5	21.36	4.16	17.86	7
Iron.....	841.5			7.06	149.9	27	183.96	21.86	14.96	25
Isabella.....	1,098				76.8	17	93.8	8.53	60.8	8
Jackson.....	1,261			4.5	60.88	2.19	67.57	5.35	12.57	9
Kalamazoo.....	1,087	1.18	4	17.64	102.18	2.75	127.75	11.75	60.75	11
Kalkaska.....	608			8.78	49.6	3.41	61.79	10.16	25.04	
Kent.....	1,694	1.5	1	3	270.17	7	282.67	16.68	72.17	19
Keweenaw.....	261			5	147	17	169	64.75	72.5	
Lake.....	607				34.37	21	55.37	9.12	46.37	
Lapeer.....	1,203			4	93.24	1	98.24	8.16	82.24	27
Leelanau.....	516			2	36.75	16	54.75	10.61	2.25	
Lenawee.....	1,498			7	64.02	11.01	82.03	5.47	30.97	
Livingston.....	987				140.68	7	147.68	14.96	92.76	17
Luce.....	205.4			1	21	11	33	16.06	20.5	9
Mackinac.....	485.1			2	23	11	36	7.42	178.65	19
Macomb.....	903		2	3.57	43.07	14	62.64	6.93	12.64	29
Manistee.....	689		3	5.34	91.8	1.12	101.26	14.69	7.26	16
Marquette.....	672		4	14.47	26.92	31	76.39	11.36	2.14	40
Mason.....	684		3	14.47	75.35	11.5	104.32	15.25	58.82	19
Mecosta.....	1,099				104.32	16	120.32	10.94	95.32	13
Menominee.....	597		2	8.4	59.34	11	80.74	13.52	99.01	29
Midland.....	663			5.98	35.95	21	62.93	9.49	43.43	34
Missaukee.....	406			1.06	57.78	24	82.84	20.4	62.09	13
Monroe.....	1,119		3	38.44	6	3	50.44	4.5	39.84	44
Montcalm.....	1,570.5			2	109.55	3.08	114.63	7.29	35.87	
Montmorency.....	273				11	5	16	5.86	11	
Muskegon.....	1,041		4	43.18	35.95	3.04	86.17	8.27	7.33	24
Newaygo.....	1,294			8.74	65.93	14	88.67	6.83	44.17	7
Oakland.....	1,676	4	2	4.11	68.87	24	102.98	6.14	33.93	27
Oceana.....	954			51.42	36.05	19	106.47	11.16	51.58	14
Ogemaw.....	608				35.55	11	46.55	7.65	27.55	17
Ontonagon.....	760			7.56	19	4	30.56	4.02	256.94	30
Oscoda.....	851			5.47	65.46	10	80.93	9.5	13.93	23
Oseoda.....	205				17	5	22	10.73	7.75	
Otsego.....	447				17	17	34	7.6	5.75	
Ottawa.....	1,206	2	2	1	40.96	14	59.96	4.97	.29	36

MICHIGAN—Continued.

TABLE 15.—*Mileage of public roads outside of incorporated cities and towns, 1914—Continued.*

County.	Total mileage of all roads.	Surfaced roads.							Graded and drained earth.	
		Con- crete.	Bitu- minous mac- adam.	Mac- adam.	Gravel.	Sand- clay.	Total of surfaced roads.	Per- centage of roads sur- faced.		In- crease in sur- faced mileage over 1909.
Presque Isle.....	580				22.89	6	28.89	4.98	— 26.11	10
Roscommon.....	240			2	25.5	9	36.5	15.2	13.75	.....
Saginaw.....	1,574		3	129.6	38.84	12.03	183.47	11.65	— 30.03	40
Sanilac.....	1,447			10	41.43	9	60.43	4.17	16.43	34
Schoolcraft.....	997			12	15	3	30	3	— 71.75	13
Shiawassee.....	1,788			3	75.95	3.4	82.35	4.6	— 4.15	15
Saint Clair.....	307	.5	3	21.69	20.75	7	52.94	17.24	37.94	17
Saint Joseph.....	987			2	33.15	2	37.15	3.76	— 38.85	.....
Tuscola.....	1,745			3.75	104.25	10	118	6.76	6.75	31
Van Buren.....	1,297			10	41.05	2.04	53.09	4.09	— 368.66	.....
Washtenaw.....	1,286				32.55	29	61.55	4.78	— 69.45	.....
Wayne.....	1,385	191	4	9	34.03	2	140.03	10.11	93.53	15
Wexford.....	903	2		5.03	95.94	4	106.97	11.84	16.97	.....
Total.....	74,189.85	107.3	94.5	1,021.19	5,230.25	1,375.27	7,828.51	10.55	927.97	1,523

¹ This includes one-half mile of brick-paved road.

MINNESOTA.

TABLE 16.—*Mileage of public roads outside of incorporated cities and towns, 1914.*

County.	Total mileage of all roads.	Surfaced roads.						Graded and drained earth.
		Mac-adam.	Gravel.	Sand-clay.	Total of surfaced roads.	Percent-age of roads surfaced.	Increase in surfaced mileage over 1909.	
Aitkin.....	1,079	.....	4	25	29	2.68	19	250
Anoka.....	664	.....	45	35	80	12.04	— 17	225
Becker.....	1,486	.....	.....	.....	.....	.....	— 20	15
Beltrami.....	1,758	.....	.....	13.08	13.08	.74	13.08	1,093
Benton.....	592	0.75	31.25	.....	32	5.4	— 14	80
Bigstone.....	837	.....	2	.....	2	.23	2	62
Blue Earth.....	1,520	1	140	.....	41	2.69	.....	143
Brown.....	971	.....	18	.....	18	1.85	— 94	21
Carlton.....	792	.....	24	15	39	4.92	— 40	175
Carver.....	600	.....	45	.....	45	7.5	— 5	20
Cass.....	1,307	.....	.....	47	47	3.51	47	60
Chippewa.....	960	.....	10	30	40	3.22	40	50
Chisago.....	535	1	25	2	28	5.23	— 12	227
Clay.....	1,775	.....	3.75	.....	3.75	.21	— 135.25	900
Clearwater.....	820	.....	.....	2	2	.24	2	40
Cook.....	295	.....	.....	.....	.....	.....	— 120	55
Cottonwood.....	1,260	.....	12	.....	12	.95	— 38	28
Crow Wing.....	628	.....	20	3	23	3.66	— 67	20
Dakota.....	945	.....	49	5	54	5.71	— 106	400
Dodge.....	810	.....	7	.....	7	.86	— 203	84
Douglas.....	1,005	.....	.....	50	50	4.97	— 125	100
Faribault.....	1,200	.....	20	50	70	5.83	21	100
Fillmore.....	1,008	2.5	5	.....	7.5	.74	7.5	50
Freeborn.....	1,150	.....	10	.....	10	.86	— 17	14
Goodhue.....	1,095	.....	19.5	1.25	20.75	1.89	— 48.25	32
Grant.....	924	.....	4	.....	4	.43	2.5	60
Hennepin.....	1,000	137	180.5	.....	117.5	11.75	.....	193
Houston.....	540	35.75	.....	3	8.75	1.62	— 3.25	74
Hubbard.....	1,200	.....	.....	71	71	5.91	70.5	.....
Isanti.....	792	1.25	14.25	.....	15.5	1.95	15.5	54
Itasca.....	952	47	20	25	52	5.46	27	400
Jackson.....	1,254	.....	20	.....	20	1.51	20	100

¹ From 1909 report.² Includes 0.5 of a mile of concrete.³ Includes 0.75 of a mile of concrete.⁴ Includes 6 miles of bituminous macadam.

MINNESOTA—Continued.

TABLE 16.—Mileage of public roads outside of incorporated cities and towns, 1914—Contd.

County.	Total mileage of all roads.	Surfaced roads.						Graded and drained earth.
		Macadam.	Gravel.	Sand-clay.	Total of surfaced roads.	Percentage of roads surfaced.	Increase in surfaced mileage over 1909.	
Kanabec.....	600			2	2	.33	2	18
Kandiyohi.....	1,210		20	160	180	14.87	— 34	300
Kittson.....	1,440		2	48	50	3.47	50	300
Koochiching.....	630							180
Lac qui Parle.....	1,435		12		12	.82	— 24	30
Lake.....	350	6	50		56	16	36	200
Le Sueur.....	730		15	1	16	2.19	— 20	50
Lincoln.....	984		9	16	25	2.54	20	42
Lyon.....	1,413						— 51	75
McLeod.....	794		150		150	18.89	—250	463.5
Mahnomen.....	244							33
Marshall.....	1,200						— 94	120
Martin.....	1,290		60		60	4.65	— 40	30
Meeker.....	1,200	1.5	100	200	301.5	25.12	285.5	200
Mille Lacs.....	655	¹ 2	¹ 31	¹ 15	48	7.32		138
Morrison.....	1,600	.75		12	12.75	.79	—448	200
Mower.....	1,440			40	40	2.77	33	100
Murray.....	1,200						— 15	40
Nicollet.....	616		178		178	28.89	73	330
Nobles.....	1,380		2	2	2	.14	2	18
Norman.....	1,632		25	25	25	1.53	25	150
Olmsted.....	1,090	6	32	38	38	3.48	—262	150
Otter Tail.....	3,000		10	10	20	.66	—118	100
Pennington.....	1,107		23		23	2.07	23	7
Pine.....	1,275		3.5		3.5	.27	— 6.5	22
Pipestone.....	860			1	1	.11	— 10	32
Polk.....	2,893		33		33	1.14	—200	1,200
Pope.....	1,150		11	11	11	.95	— 14	11
Ramsey.....	211	² 51.5	98		149.5	70.85	95.9	17
Red Lake.....	725		6.5		6.5	.89	— 53.5	13
Redwood.....	1,600		60	60	60	3.75	— 44	100
Renville.....	1,648		38	38	38	2.30	— 59	520
Rice.....	980		260	10	270	27.5	136	30
Rock.....	930		13		13	1.39	13	
Roseau.....	2,000		3		3	.15	— 48	839
St. Louis.....	3,000		400		400	13.33	275	2,309
Scott.....	560		29		29	5.17	9	12
Sherburne.....	750	2	30	40	72	9.60	61	300
Sibley.....	735		70		70	9.52	30.5	60
Stearns.....	2,000		100		100	5	49.5	125
Steele.....	711	³ 25	155		155.25	21.83	25.25	100
Stevens.....	800						— 10	50
Swift.....	800		25	10	35	4.37	— 43	100
Todd.....	1,355	.5		20	20.5	1.51	— .50	150
Traverse.....	998		7		7	.7	7	60
Wabasha.....	847		15	10	25	2.95	— 5	225
Wadena.....	678		1		1	.14		100
Waseca.....	711		25		25	3.51	4	52
Washington.....	674		65	1	66	9.79	65	8
Watonwan.....	600			7	7	1.16	— 53	40
Wilkin.....	1,186							87
Winona.....	1,000	⁴ 30.5	5		35.5	3.55	3.5	200
Wright.....	1,105		100	5	105	9.50	— 35	200
Yellow Medicine.....	1,740		24		24	1.37	— 58	16
Total.....	93,517	⁵ 157.25	2,825.25	985.33	3,967.83	4.24	—1,449.02	15,377.5

¹ From 1909 report.² Includes 13 miles of bituminous macadam.³ Includes 0.25 of a mile of concrete.⁴ Includes 16 miles of concrete and 0.5 of a mile of brick.⁵ Includes 17.5 miles of concrete, 19 miles bituminous macadam and 0.5 of a mile of brick

MISSOURI.

TABLE 17.—*Mileage of public roads outside of incorporated cities and towns, 1914.*

County.	Total mileage of all roads.	Surfaced roads.						Graded and drained earth.	
		Bitumi- nous mac- adam.	Mac- adam.	Gravel.	Sand- clay.	Total of surfaced roads.	Per- centage of roads sur- faced.		Increase in sur- faced mileage over 1909.
Adair.....	1,200								1,100
Andrew.....	755		.5			.5	.06	— .5	400
Atchison.....	1,012								800
Audrain.....	1,148		5			5	.43	5	
Barry.....	900							— 33	600
Barton.....	850			7		7	.82	2	
Bates.....	1,363			3	110	113	8.29	113	1,000
Benton.....	952.75			77.75		77.75	8.16	69.75	475
Bollinger.....	308			8	10	18	5.82	14	50
Boone.....	1,458	4	4	50		58	3.97	—1	1,000
Buchanan.....	970.75	.75	30			30.75	3.16	12.75	100
Butler.....	615			15		15	2.43	13	500
Caldwell.....	800.5		.5			.5	.06	.5	
Callaway.....	1,420		7	43		50	3.52	25	50
Camden.....	700								50
Cape Girardeau	850		14	160		174	21.64	—12	500
Carroll.....	800							— .5	300
Carter.....	140			5		5	3.57	5	
Cass.....	1,323		6			6	.45	— 2	800
Cedar.....	900			5		5	.55	5	
Chariton.....	1,350								
Christian.....	820			20	100	120	14.63	120	100
Clark.....	1,500								
Clay.....	706.5							— 2.5	513.25
Clinton.....	470								400
Cole.....	540.5		37.05	157		194.05	35.9	12.55	42.94
Cooper.....	900			3	100	103	11.44	101	600
Crawford.....	325		5	20	50	75	23.07	75	50
Dade.....	975			47		47	4.82	47	700
Dallas.....	925			11.25		11.25	1.21	11.25	340
Daviess.....	263		3			3	1.14	1	160
DeKalb.....	400								200
Dent.....	375							— 5	100
Douglas.....	1,200								14
Dunklin.....	400							— 5	
Franklin.....	1,600	4	35	200		239	14.93	—61	50
Gasconade.....	260		30	80		110	42.3	—171	120
Gentry.....	902								853
Greene.....	1,464	2	90.5	43		135.5	9.25	39	1,053.5
Grundy.....	600								250
Harrison.....	300	.5		13		3.5	1.16	3.5	296.5
Henry.....	1,050								500
Hickory.....	510			50	60	110	21.56	105	100
Holt.....	750				175	175	23.33	175	400
Howard.....	668								92.9
Howell.....	1,000								300
Iron.....	300			45	20	65	21.66	25	85
Jackson.....	1,100		250			250	22.72	32	95
Jasper.....	298.5		25.5	101		126.5	42.37	—427.5	52
Jefferson.....	1,172		150	230		380	32.42	240	380
Johnson.....	1,494	.5	2			2.5	.16	1	200
Knox.....	730								690
Laclede.....	1,200							— 5	100
Lafayette.....	1,040	.75	20			20.75	1.99	20.75	1,018
Lawrence.....	2,172		132		400	532	24.49	474	1,350
Lewis.....	830			24	6	30	3.61		200
Lincoln.....	1,219		15.5	152		167.5	13.74	119.5	
Linn.....	1,000								700
Livingston.....	850							— 2	243.2
McDonald.....	1,340				40	40	2.97	40	100
Macon.....	2,000							— 2	
Madison.....	854			10		10	1.17		
Maries.....	1,000			100		100	10	100	
Marion.....	800	15	35	75		125	15.62	—110	275
Mercer.....	1,100								
Miller.....	1,897			25	25	50	2.63	50	275
Mississippi.....	360.25				1.25	1.25	.34	.25	200
Moniteau.....	450			50		50	11.11	—100	
Monroe.....	1,000			50		50	5	—120	700

1 1 mile brick and 2 miles concrete.

MISSOURI—Continued.

TABLE 17.—Mileage of public roads outside of incorporated cities and towns, 1914—Continued.

County.	Total mileage of all roads.	Surfaced roads.						Graded and drained earth.	
		Bitumi- nous mac- adam.	Mac- adam.	Gravel.	Sand- clay.	Total of surfaced roads.	Per- centage of roads sur- faced.		Increase in sur- faced mileage over 1909.
Montgomery...	780			30		30	3.84	24	300
Morgan.....	400			50		50	12.5	— 25	300
New Madrid...	426			2	10	12	2.81	12	100
Newton.....	800			175		175	21.87	75	625
Nodaway.....	1,500								1,500
Oregon.....	700			120		120	17.14	120	80
Osage.....	800		10	125	200	335	41.87	235	150
Ozark.....	773								100
Pemiscot.....	173		8			8	4.62	5.25	100
Perry.....	784		18	100		118	15.05	— 57	500
Pettis.....	1,225	10	60	90		160	13.06	102.5	800
Phelps.....	830			30		30	3.61	30	325
Pike.....	1,050		3	198		201	19.14	65.5	
Platte.....	700		1			1	.14	1	
Polk.....	800			20	20	40	5	40	100
Pulaski.....	350							— 20	6
Putnam.....	800								400
Ralls.....	735			70		70	9.52	—130	350
Randolph.....	650	18				18	2.76	16	350
Ray.....	1,000								100
Reynolds.....	88			3		3	3.40	3	10
Ripley.....	1,080								40
St. Charles.....	940		25	130	5	160	17.02	— 10	750
St. Clair.....	419			4	15	19	4.53	19	100
Ste. Genevieve.	500		50	100	20	170	34	65	280
St. Francois.....	500	2	58	90		150	30	112	200
St. Louis.....	1,100.77		375	125	1.77	500.77	45.49	74.77	600
Saline.....	1,200.5	.5				.5	.04	.5	800
Schuyler.....	600								
Scotland.....	800								800
Scott.....	560.5	.5	15.5	15.5	25	56.5	10.08	50.25	200
Shannon.....	850			100		100	11.76	100	550
Shelby.....	705			20		20	2.83		
Stoddard.....	1,200			40		40	3.33	30	
Stone.....	467			7		7	1.49	7	50
Sullivan.....	1,122								
Taney.....	500								4
Texas.....	605			5	50	55	9.09	55	50
Vernon.....	1,514.25	.5		2.5		5.5	3.36	5.5	1,451.75
Warren.....	507			35		35	6.9	— 56	128
Washington.....	275			50		50	18.18	— 35	100
Wayne.....	320			20		20	6.25		
Webster.....	800		10	50		60	7.5	54	300
Worth.....	442								382
Wright.....	742							— 10	100
Total....	96,040.77	59	1,531.05	3,679.50	1,443.02	6,712.57	6.98	1,957.07	34,706.04

¹ Concrete, 0.77 mile.² Cinders, 5 miles.

MONTANA.

TABLE 18.—*Mileage of public roads outside of incorporated cities and towns, 1914.*

County.	Total mileage of all roads.	Surfaced roads.						Graded and drained earth.
		Macadam.	Gravel.	Other hard-surfaced roads.	Total of surfaced roads.	Percentage of roads surfaced.	Increase in surfaced mileage over 1909.	
Beaverhead.....	1,033							100
Big Horn.....	352							171
Blaine.....	1,248							220
Broadwater.....	482		2		2	.41	2	80
Carbon.....	812		4	¹ 12	16	1.97	16	110
Cascade.....	1,427	.5			.5	.03	.5	54
Chouteau.....	2,400			¹ 2				400
Custer.....	2,116		12	² 3	17	.80	17	490
Dawson.....	2,530		30		30	1.18	20	100
Deer Lodge.....	175	75			75	42.85	61	100
Fallon.....	518							300
Fergus.....	4,280		5		5	.11	.5	275
Flathead.....	1,621	2	220		222	13.69	222	224
Gallatin.....	943	.5	.25		.75	.07	.25	375.55
Granite.....	250							50
Hill.....	1,000							125
Jefferson.....	357							157
Lewis and Clarke.....	1,144		100		100	11.44	80	250
Lincoln.....	520		10		10	1.92	10	200
Madison.....	1,280						— 25	250
Meagher.....	950							60
Mineral.....	135							85
Missoula.....	766		65		65	8.48	55	305
Musselshell.....	866		6		6	.69	6	60
Park.....	500							125
Phillips.....	1,000		2.5		2.5	.25	2.5	147.5
Prairie.....	908		8		8	.88	8	24
Powell.....	500							80
Ravalli.....	720		20		20	2.77	10	100
Richland.....	625		5		5	.80	5	120
Rosebud.....	750						— 1	250
Sanders.....	575							225
Sheridan.....	1,475							50
Silver Bow.....	332		12		12	3.61	12	70
Stillwater.....	300							25
Sweet Grass.....	410		10		10	2.43	10	100
Teton.....	1,334							125
Toole.....	550							200
Valley.....	920							20
Wibaux.....	300							25
Yellowstone.....	800		2.5		2.5	.31	2.5	300
Total.....	39,204	78	514.25	17	609.25	1.55	514.25	6,528.05

¹ Sand-clay.² Shale.

NEBRASKA.

TABLE 19.—*Mileage of public roads outside of incorporated cities and towns, 1914.*

County.	Total mileage of all roads.	Surfaced roads.					Graded and drained earth.
		Sand-clay.	Other hard-surfaced roads.	Total of surfaced roads.	Percentage of roads surfaced.	Increase in surfaced mileage over 1909.	
Adams.....	1,232						
Antelope.....	1,025	25		25	2.43	25	100
Arthur.....	300						
Banner.....	445						
Blaine.....	150						
Boone.....	500						200
Box Butte.....	500						200
Boyd.....	672	2		2		2	180
Brown.....	226	1		1		1	75
Buffalo.....	1,500	22		22	1.46	21	
Burt.....	775						250
Butler.....	1,150						650
Cass.....	1,086						436
Cedar.....	1,500		1 1	1		-129.5	
Chase.....	500					-10	10
Cherry.....	1,600	50		50	3.12	50	50
Cheyenne.....	1,269	90		90	7.09	90	60
Clay.....	550						400
Colfax.....	701		2 1	1		1	250
Cumming.....	1,074						
Custer.....	3,700	200		200	5.4	200	500
Dakota.....	508						
Dawes.....	965						50
Dawson.....	1,510	10		10	.66	10	500
Deuel.....	245						20
Dixon.....	700						
Dodge.....	1,041		3 2.0	2		1.75	1,039
Douglas.....	675		4 41.88	41.88	6.2	-14.92	500
Dundy.....	200						20
Fillmore.....	1,152						105
Franklin.....	1,053					-10	553
Frontier.....	1,100						150
Furnas.....	1,000						300
Gage.....	864					-1	300
Garden.....	600						
Garfield.....	800						
Gosper.....	850						300
Grant.....							
Greeley.....	70						20
Hall.....	1,026	25	5 1	26	2.53	26	800
Hamilton.....	1,800						1,500
Harlan.....	1,000						400
Hayes.....	500						
Hitchcock.....	850	2		2		2	120
Holt.....	500						200
Hooker.....	152		6 2	2		2	
Howard.....	1,200						400
Jefferson.....	200	2		2		2	
Johnson.....	759						700
Kearney.....	1,012	3		3			670
Keith.....	400						
Keyapaha.....	540	40		40	7.4	40	
Kimball.....	320						20
Knox.....	700	20		20	2.85	20	90
Lancaster.....	2,001		7 1.0	1		1	1,000
Lincoln.....	1,500	10	1 10	20	1.33	20	150
Logan.....	212						30
Loup.....	270						20
McPherson.....	500						
Madison.....	1,172	400		400	34.12	394	500
Merrick.....	960	5		5		5	864
Morrill.....	660		2 2	2		2	150
Nance.....	900						
Nemaha.....	745		5 1.5	1.5			
Nuckolls.....	1,100						500

¹ Gravel.² Macadam.³ 0.5 mile concrete; 1.5 miles gravel.⁴ Concrete, 3.53; macadam, 35.65; brick, 1.9; bituminous macadam, 0.8.⁵ Concrete.⁶ Gypsum.⁷ 0.5 mile brick; 0.5 mile bituminous macadam.

NEBRASKA—Continued.

TABLE 19.—*Mileage of public roads outside of incorporated cities and towns, 1914—Con.*

County.	Total mileage of all roads.	Surfaced roads.					Graded and drained earth.
		Sand-clay.	Other hard-surfaced roads.	Total of surfaced roads.	Percentage of roads surfaced.	Increase in surfaced mileage over 1909.	
Otoe.....	1,225						
Pawnee.....	884						
Perkins.....	520						
Phelps.....	1,015					— 4	800
Pierce.....	1,152	15		15	1.3	15	704
Platte.....	1,150						850
Polk.....	820						525
Redwillow.....	926		¹ 1	1		1	325
Richardson.....	982		² .56	.56		.56	129.5
Rock.....	400						
Saline.....	1,500						1,000
Sarpy.....	400						150
Saunders.....	1,685	3.6		3.6		3.6	1,671.4
Scotts Bluff.....	609	.5	³ 8.5	9	1.47	9	250
Seward.....	500						400
Sheridan.....	780						233
Sherman.....	2,700	200		200	7.4	200	1,800
Sioux.....	745						
Stanton.....	900					— 4.50	400
Thayer.....	1,096						
Thomas.....	150	5		5	3.33	5	
Thurston.....	411						26
Valley.....	330						150
Washington.....	600						400
Wayne.....	931						931
Webster.....	864						464
Wheeler.....	450					— 20	
York.....	1,300						1,000
Total.....	80,272	1,131.1	73.44	1,204.54	1.5	955.99	27,540.9

¹ Concrete.² Macadam.³ Gravel.

NEVADA.

TABLE 20.—*Mileage of public roads outside of incorporated cities, 1915.*

County.	Total mileage of all roads.	Surfaced roads.					Graded and drained earth.
		Gravel.	Sand-clay.	Total of surfaced roads.	Percentage of roads surfaced.	Increase in surfaced mileage over 1909.	
Churchill.....	766	¹ 1	5	6	0.77	6	
Clark.....	1,170						
Douglas.....	143	¹ 50		51	35.66	48	92
Elko.....	1,645						300
Esmeralda.....	341		20	20	5.87	20	80
Eureka.....	405						
Humboldt.....	1,400						
Lander.....	734						
Lincoln.....	646						
Lyon.....	721						
Mineral.....	1,134						
Nye.....	819						
Ormsby.....	50	3	2	5	10	— 1	15
Storey.....	30					— 20	25
Washoe.....	1,148	140	40	180	15.67	170	568
White Pine.....	1,030						
Total.....	12,182	195	67	262	2.14	216	1,060

¹ Crushed rock.

NEW MEXICO.

TABLE 21.—*Mileage of public roads outside of incorporated cities and towns, 1914.*

County.	Total mileage of all roads.	Surfaced roads.					Graded and drained earth.
		Gravel.	Sand- clay.	Total of surfaced roads.	Percent- age of roads surfaced.	Increase in surf- aced mileage over 1909.	
Bernalillo.....	240	20		20	8.33	20	40
Chaves.....	543	2	10	12	2.2	12	75
Colfax.....	496						200
Curry.....	222		15	15	6.75	15	35
Dona Ana.....	432	195	10	105	24.3	105	130
Eddy.....	368						100
Grant.....	554						150
Guadalupe.....	536						60
Lincoln.....	468	4		4	.85	4	75
Luna.....	348	5	25	30	8.62	27	60
McKinley.....	422						50
Mora.....	326	3		3	9.2	3	45
Otero.....	338	20		20	5.91	-31	60
Quay.....	430						50
Rio Arriba.....	508					-50	30
Roosevelt.....	326						50
Sandoval.....	364	10	4	14	3.84	14	35
San Juan.....	500						60
San Miguel.....	460						125
Santa Fe.....	300						50
Sierra.....	446	12		12	2.69	12	75
Socorro.....	1,092	15		15	1.37	15	100
Taos.....	326						50
Torrance.....	500						25
Union.....	800		1.5	1.5	.18	1.5	118.5
Valencia.....	528	3	7	10	1.89	10	58
Total.....	11,873	189	72.5	261.5	2.2	157.5	1,906.5

¹ Includes 5 miles bituminous macadam.

NORTH DAKOTA.

TABLE 22.—*Mileage of public roads outside of incorporated cities and towns, 1914.*

County.	Total mileage of all roads.	Surfaced roads.			Graded and drained earth.
		Total of surfaced roads (all gravel).	Percentage of roads surfaced.	Increase in surfaced mileage over 1909.	
Adams.....	1,000				200
Barnes.....	2,506	6.5	0.25	- 3.5	1,000
Benson.....	1,247	47	3.76		400
Billings.....	500			- 8	500
Bottineau.....	1,620	20	1.23	15	400
Bowman.....	1,160				360
Burke.....	1,131	31	2.74	31	400
Burleigh.....	1,162	2	.17		210
Cass.....	3,200				2,500
Cavalier.....	1,934	4.5	.23	1.5	1,260
Dickey.....	1,072	32	2.98	30	400
Divide.....	1,800				600
Dunn.....	1,000				350
Eddy.....	315	15	4.76	13	100
Emmons.....	1,020				50
Foster.....	1,305	5	.38	3	200
Golden Valley.....	340				40
Grand Forks.....	2,890	160	6.63	150	1,650
Griggs.....	550	90	16.36	85	260
Hettinger.....	1,235				135
Kidder.....	785				85
Lamoure.....	1,605	5	.31	2	600
Logan.....	1,150				150
McHenry.....	2,050	50	2.43	45	800
McIntosh.....	336			- 3	66

NORTH DAKOTA—Continued.

TABLE 22.—Mileage of public roads outside of incorporated cities and towns, 1914—Continued.

County.	Total mileage of all roads.	Surfaced roads.			Graded and drained earth.
		Total of surfaced roads (all gravel).	Per-centage of roads surfaced.	Increase in surfaced mileage over 1909.	
McKenzie.....	500				15
McLean.....	2,810	10	.35	5	300
Mercer.....	400				30
Morton.....	2,935			—10	335
Mountrail.....	2,000				200
Nelson.....	1,130	30	2.65	25	500
Oliver.....	500				
Pembina.....	1,504	4	.26	4	1,000
Pierce.....	1,310	10	.76	10	600
Ramsey.....	1,340	40	2.98	28	500
Ransom.....	1,220	20	1.78	20	600
Renville.....	804	14	1.73	14	240
Richland.....	2,100				1,500
Rolette.....	2,200	250	11.36	245	450
Sargent.....	1,700				800
Sheridan.....	1,000				100
Sioux.....	200				
Slope.....	600				100
Stark.....	953	3	.31	— 2	200
Steele.....	1,015	15	1.47	12	400
Stutsman.....	2,150	50	2.32	50	600
Towner.....	770			— 5	420
Trail.....	1,710	10	.58	5	1,600
Walsh.....	1,900			— 5	1,200
Ward.....	902	2	.22	— 8	100
Wells.....	1,500			— 5	500
Williams.....	729	29	3.97	29	300
Total.....	68,796	955	1.38	815	25,306

OHIO.

TABLE 23.—Mileage of public roads outside of incorporated cities and towns, 1914.

County.	Total mileage of all roads.	Surfaced roads.									Graded and drained earth.
		Macadam.	Bituminous macadam.	Gravel.	Brick.	Concrete.	Miscellaneous.	Total of surfaced roads.	Percentage of roads surfaced.	Increase in surfaced mileage over 1909.	
Adams.....	915	243		100			186	429	46.88	120	146
Allen.....	934	748.7	6.5	30	10.25	4.2		799.65	85.49	279.65	
Ashland.....	955.24	50	14.25	8	6.62	.5		79.37	8.3	61.37	
Ashtabula.....	1,261	36.86		5	5.25	6.11		53.22	4.22	17.22	
Athens.....	1,005	97		10	9			116	11.53	— 12	
Auglaize.....	850	15	1	674				690	81.17	306	100
Belmont.....	1,300		84.95		38.1	2		125.05	9.6	— .05	
Brown.....	864	203		114				317	36.68	11	547
Butler.....	814		143.8	558.60	5.5			707.9	86.9	— 163.1	
Carroll.....	1,000.5				3.5			3.5	.34	3.5	
Champaign.....	1,802	15	1			2		18	2.24	— 444	
Clark.....	862	50	5	782				837	97.09	— 25	
Clermont.....	987	299.5				1		300.5	30.44	— 134.5	
Clinton.....	835	150	8	475				633	75.8	— 46	42
Columbiana.....	1,333.5	1.5	2		30			33.5	2.51	15.5	
Coshocton.....	1,143	2		110	2.5	2.5		117	10.23	43	300
Crawford.....	870.25	330	2.5	28	9.75			370.25	42.5	80.25	500
Cuyahoga.....	572		1		128			129	22.5	— 24	4.5
Darke.....	1,290.8	51	3	1,023.8		7		1,084.8	84.04	324.8	206
Defiance.....	855	30		429		5.3		464.3	54.3	5.3	
Delaware.....	828.4	535		20	.4			555.4	67.04	82.4	50
Erie.....	460	165	9	28		15	28	245	53.26	— 37	45

¹ Sand-clay.² Worn macadam, 277.³ Slate.

OREGON.

TABLE 24.—*Mileage of public roads outside of incorporated cities and towns, 1914.*

County.	Total mileage of all roads.	Surfaced roads.						Graded and drained earth.	
		Mac- adam.	Bitumi- nous mac- adam.	Gravel.	Other hard- sur- faced roads.	Total of sur- faced roads.	Per- centage of roads sur- faced.		Increase in sur- faced mileage over 1909.
Baker	2,100			30		30	1.42	25	25
Benton	566	25		141		166	29.32	166	25
Clackamas	1,316	103	7	162	¹ 91	363	27.58	83	
Clatsop	250	62	2	9	² 4	77	30.8	2	42
Columbia	355.75	39.75	5	68.75		113.5	31.9	— 36.5	58.75
Coos	695	60		30	⁴ 55	145	20.86	60	
Crook	2,100			50	³ 260	310	14.76	300	500
Curry	155			36	⁴ 50	86	55.45	70	
Douglas	1,800	20		250		270	15	193	300
Gilliam	525			4		4	.77	4	
Grant	830			11		11	1.32	10	
Harney	2,000	4		4		8	.4	—107	100
Hood River	270	20.50		12		32.5	12.03	— .5	
Jackson	800	30	5	100	² 12	147	18.37	— 10	200
Josephine	418	8		40		48	11.48	36	150
Klamath	850	2		10		12	1.41	— 2	50
Lake	750			50		50	6.66	— 30	
Lane	1,567.37	133.47		402.4	⁵ 27.5	563.37	35.94	54.37	
Lincoln	400	6		10		16	.4	16	
Linn	1,860	60		600		660	41.25	350	400
Malheur	1,600			5		5	.31	5	
Marion	3,002	80	2	80		162	5.39	82	100
Morrow	950	13				13	1.36	13	
Multnomah	510.73	96	63	105	⁶ 10.03	274.03	53.79	44.73	108
Polk	1,118	10	8	390		408	36.49	284	360
Sherman	600			2		2	.33	2	100
Tillamook	310.33	50	.25	125	⁷ 8.75	184	59.29	61	15
Umatilla	3,500		30	12		42	1.2	41	500
Union	800	3		25		28	3.5	8.75	100
Wallowa	950			10		10	1.05	— 5	300
Wasco	1,000	25	15	100		140	14	128	360
Washington	1,077	100		30		130	12.07	70	50
Wheeler	493			6		6	1.21		
Yamhill	1,300	50		150		200	15.36		900
	36,819.18	1,000.72	137.25	3,060.15	518.28	4,716.4	12.81	1,917.85	4,718.75

¹ Plank.² Concrete.³ 250 miles sand-clay; 10 miles volcanic cinders.⁴ Sand-clay.⁵ Plank corduroy.⁶ 0.37 miles wood block; 9.66 miles concrete.⁷ 2.75 miles concrete; 6 miles plank.

SOUTH DAKOTA.

TABLE 25.—*Mileage of public roads outside of incorporated cities and towns, 1914.*

County.	Total mileage of all roads.	Surfaced roads.						Graded and drained earth.
		Gravel.	Sand-clay.	Other hard-surfaced roads.	Total of surfaced roads.	Percentage of roads surfaced.	Increase in surfaced mileage over 1909.	
Aurora.....	1,440							59
Beadle.....	1,470							125
Bennett ¹								
Bonhomme.....	1,077							533
Brookings.....	1,584	5			5	.31	5	400
Brown.....	2,856	12			12	.42	12	1,200
Brule.....	1,500						— 5	100
Buffalo.....	500						— 5	10
Butte.....	810							40
Campbell.....	75							75
Charles Mix.....	1,300							300
Clark.....	1,946							589
Clay.....	798						— 25	798
Codington.....	1,110	10			10	.9	5	1,100
Corson.....	227.5							106.5
Custer.....	500							50
Davison.....	450	10			10	2.22	— 8	65
Day.....	2,000	10			10	.5	10	30
Deuel.....	1,260							1,000
Dewey.....	2,500						— 6	1,000
Douglas.....	1,016							
Edmunds.....	2,304		1		1	.04	— 23	50
Fall River.....	370							120
Faulk.....	2,012							4
Grant.....	1,564							
Gregory.....	1,200							300
Haakon.....	3,600							
Hamlin.....	650							200
Hand.....	2,876	2			2	.06	2	100
Hanson.....	912	3			3	.32	— 1	20
Harding.....	5,000							300
Hughes.....	1,000	4			4	.4	4	200
Hutchinson.....	1,652							
Hyde.....	1,741							12
Jerauld.....	486							150
Kingsbury.....	864	40			40	4.62	40	624
Lake.....	600	5			5	.83	5	300
Lawrence.....	800	4	100	12	116	14.50	116	200
Lincoln.....	1,500	70		² 10	80	5.33	79	1,100
Lyman.....	³ 3,000							
McCook.....	1,000							
McPherson.....	1,500							300
Marshall.....	1,440	10	3		13	.90	13	450
Meade.....	2,595		20		20	.77	— 55	1,000
Mellette.....	200							5
Miner.....	1,172							
Minnehaha.....	1,632							1,632
Moody.....	1,060							100
Pennington.....	5,548							
Perkins.....	5,766							
Potter.....	1,500							100
Roberts.....	¹ 1,162	18			18	1.54		
Sanborn.....	880						— 50	80
Shannon.....	² 1,000							
Spink.....	3,000	4			4	.13	4	496
Stanley.....	² 2,000							
Sully.....	2,160						— 50	
Todd ¹								
Tripp.....	² 1,400							
Turner.....	620							460
Union.....	936	5			5	.53	5	624
Walworth.....	585		5		5	.85	5	30
Washabaugh.....	³ 400							
Washington.....	(⁴)							
Yankton.....	1,500							300
Ziebach.....	700							
Total.....	96,306.5	212	129	22	363	.37	77	17,071.5

¹ New county.² Macadam with bitumen.³ Mileage report for 1909.⁴ No report received.

UTAH.

TABLE 26.—*Mileage of public roads outside of incorporated cities and towns, 1914.*

County.	Total mileage of all roads.	Surfaced roads.						Graded and drained earth.
		Gravel.	Sand-clay.	Other hard-surfaced roads.	Total of surfaced roads.	Percentage of roads surfaced.	Increase in surfaced mileage over 1909.	
Beaver.....	55	30	.....	.....	30	54.54	10	.....
Boxelder.....	1,500	250	220	¹ 5	475	31.66	475	725
Cache.....	400	35	.....	.....	35	8.75	.....	.....
Carbon.....	187	.....	.....	.....	.....	.....	-125	61
Davis.....	100	.....	.....	.....	.....	.....	- 74	50
Emery ²	160	.....	41	.....	41	25.62	.....	.....
Garfield.....	500	10	.....	.....	10	2	10	27
Grand.....	300	18	4	.....	22	7.33	11	20
Iron.....	248	.....	.....	.....	.....	.....	- 3	97
Juab.....	200	60	.....	.....	60	30	53	140
Kane.....	100	.....	15	.....	15	15	15	14
Millard.....	250	.....	100	.....	100	40	95.5	.....
Morgan.....	101	2	.....	³ 13	15	14.85	12	11
Piute.....	109	9	20	.....	29	26.6	- 21	.....
Rich.....	220	20	.....	.....	20	9.09	- 15	50
Salt Lake.....	400	125	.....	⁴ 9	134	33.5	- 74.5	100
San Juan.....	167	.....	.....	.....	.....	.....	- 18	167
Sanpete.....	400	.....	.....	.....	.....	.....	.....	400
Sevier.....	293	29.5	.....	.....	29.5	10.05	-180.5	66
Summit.....	210	15	.....	⁵ 5	15.5	7.38	10.5	42
Toole.....	⁶ 1,000	10.25	.....	.....	10.25	1.02	6.25	10.61
Uinta.....	604	.....	.....	.....	.....	.....	- 13	237
Utah ²	400	40	.....	³ 5	45	11.25	.....	.....
Wasatch.....	124	.....	.....	.....	.....	.....	- 22	55
Washington.....	230	.....	.....	.....	.....	.....	.....	55
Wayne.....	127	3	.....	.....	3	2.37	3	32
Weber.....	425	29	1	⁷ 34.5	64.5	15.17	- 19.5	43.5
Total.....	8,810	685.75	401	67	1,153.75	13.09	135.75	2,403.11

¹ Concrete, 2; bituminous macadam, 3.² Mileage report for 1909.³ Macadam.⁴ Macadam, 8; bituminous macadam, 1.⁵ Concrete.⁶ Total mileage from 1909 report.⁷ Macadam, 23; bituminous macadam, 11.5.

WASHINGTON.

TABLE 27.—*Mileage of public roads outside of incorporated cities and towns, 1914.*

County.	Total mileage of all roads.	Surfaced roads.									Graded and drained earth.	
		Macadam.	Bituminous macadam.	Gravel.	Sand-clay.	Brick.	Concrete.	Other hard-surfaced roads.	Total of surfaced roads.	Percentage of roads surfaced.		Increase in surfaced mileage over 1909.
Adams.....	2,318.85		6.85	17					23.85	1.02	23.85	1,200
Asotin.....	450.6	1.5	.1	5					6.6	1.46	6.6	20
Benton.....	975.4	12	10.4	25					47.4	4.85	42.65	100
Chelan.....	730			27					27	3.69	25.67	52
Clallam.....	230.5			152.5					152.5	66.16	62.5	20
Clarke.....	1,300	90	22	150			3		265	20.38	52	75
Columbia.....	480	12		14	10				36	7.5	34.5	10
Cowlitz.....	598.75	35	2.5	20			1.25	140	98.75	16.49	69.75	100
Douglas.....	2,328.8	12.2		16.6					28.8	1.23	305.2	500
Ferry.....	770	3							3	.38	3	20
Franklin.....	1,400	1.5	2	1.5			2.5		7.5	.53	7.5	400
Garfield.....	501.6	1.6							1.6	.51	1.6	30
Grant.....	2,398	23		10					33	1.42	29	150
Grays Harbor ^a	494.21		.47	282			4.74	^a 80	367.21	74.3	94.21	39
Island.....	224.14			61.84	1.25				63.09	28.14	5.2	53.68
Jefferson.....	240			56					56	23.33	56	60
King.....	1,589.03		25.4	1,057.8		23.4	6.33		1,112.93	70.03	499.8	276.1
Kitsap.....	758.5			89.25	61.75				151	19.9	151	211
Kittitas.....	643.4		2.2	40		1.2			43.4	6.74	43.15	200
Klickitat.....	1,675.3	5.6	10.2	9	.5				25.3	1.51	25.3	550
Lewis.....	1,100	80	.49	45			12.47		137.96	12.54	34.46	300
Lincoln.....	3,100.5	29		50			.5		79.5	2.82	79.5	800
Mason.....	450.25			83.25					83.25	18.48	96.75	114
Okanogan.....	1,850.1	27.2		11.46					38.66	2.08	38.66	15
Pacific.....	237.75	30		29			.75	⁴ 18	77.75	32.7	19.55	102
Pend Oreille.....	508			8					8	1.57	8	100
Pierce.....	973.87	7.76	10.14	354.22		.75	28.02		400.89	41.78	44.26	200.48
San Juan.....	200.45	.75		18.75					19.5	9.72	64.75	35
Skagit.....	763.75	4		380			6.75		390.75	51.16	14.75	273
Skamania.....	152	2.5		15					17.5	11.51	13.5	109
Snohomish.....	764.55	1.5		429.5		1	3.55		435.55	56.96	390.45	329
Spokane.....	2,399.78	35.12	34	14.66					83.78	3.49	14.28	60
Stevens.....	2,014.24	7.09		7.15					14.24	.70	12.24	120
Thurston.....	776	7							7	.90	148	223
Wahkiakum.....	109	18		9				⁴ 2	29	26.6	4	50
Walla Walla.....	1,435.06	30	5	50			.06		85.06	5.92	79.93	1,000
Whatcom.....	750			260			9.5		269.5	35.93	258	100
Whitman.....	2,700	15.5	18		10				43.5	1.61	34.85	1,328.5
Yakima.....	2,125.77	10	15.77	125					150.77	7.09	127.82	125
Total.....	42,428.15	502.82	165.52	3,924.48	83.5	26.35	79.42	140	4,922.09	11.61	401.41	9,450.76

¹ 15 miles plank; 25 miles corduroy.² This was Chehalis County in 1909.³ 64 miles plank; 16 miles corduroy.⁴ Plank.

WISCONSIN.

TABLE 28.—*Mileage of public roads outside of incorporated cities and towns, 1914.*

County.	Total mileage of all roads.	Surfaced roads.							In- crease in sur- faced mileage over 1909.	Graded and drained earth.	
		Mac- adam.	Bitu- minous mac- adam.	Gravel.	Sand- clay.	Con- crete.	Other hard- sur- faced roads.	Total of surfaced roads.			Per- centage of roads sur- faced.
Adams.....	1,111	1	1		26			28	2.52	22	184
Ashland.....	513	12		44	11		8	75	14.6	53	226
Barron.....	1,591			2	40			42	2.63	29	846
Bayfield.....	837				2		3	5	.59	45	473
Brown.....	1,064	112	2	172	44	1.5		331.5	31.1	18.5	399
Buffalo.....	1,097		6	2	33			41	3.73	7	279
Burnett.....	1,172			50	10			60	5.11	32	276
Calumet.....	637	4	1	381	13			399	62.6	24	111
Chippewa.....	1,273	4		75	140			219	17.2	187	538
Clark.....	1,621	1		37	48			86	5.3	51	1,045
Columbia.....	1,334.07	40	19	141	26	.07	3	229.07	17.17	45.07	570
Crawford.....	1,086			10	6			16	1.47	0	100
Dane.....	2,248	74	45	231	26	1.5	2	379.5	16.8	60.5	920
Dodge.....	1,591	34	13	467	31	.5		545.5	34.2	96.5	518
Door.....	980	94		182	5			281	28.6	82	384
Douglas.....	999	11		34	5	2.4		52.4	5.24	38.4	356
Dunn.....	1,480	1		34	90			125	8.44	78.67	511
Eau Claire.....	993	9		59	164			232	23.3	136	424
Florence.....	221	6	3	20	9		16	54	24.4	28	82
Fond du Lac.....	1,296	28	3	449	43	1.5		524.5	40.4	66.5	429
Forest.....	299	1						1	.33	22	110
Grant.....	2,070	87		126	37		2	252	12.17	137	859
Green.....	1,070	88		96	16	.9		200.9	18.77	137.9	362
Green Lake.....	568	7	4	77	31			119	20.9	45	222
Iowa.....	1,142	5		20		.6		25.6	2.24	35.4	524
Iron.....	196	2		5			16.4	23.4	11.9	10.4	108
Jackson.....	1,474		6	132	51			138	9.36	48	498
Jefferson.....	907	24	13	172	17			260	28.6	18	330
Juneau.....	1,227	12		3	22	.1		37.1	3.02	6.1	441
Kenosha.....	486	12		161	17	11		201	41.3	83	162
Kewaunee.....	724	12		280	8			300	41.4	71	236
La Crosse.....	719	34	23	35				92	12.7	47	291
Lafayette.....	1,142	11	3	15	3	.5		32.5	2.84	28.5	584
Langlade.....	710			13	21			34	4.78	9	394
Lincoln.....	737			33	38			71	9.63	18	364
Manitowoc.....	1,274	23		699		1		723	56.7	346	296
Marathon.....	2,218	25		86	29			140	6.31	54	1,269
Marquette.....	1,245	20		114	15		4	153	12.28	66	545
Marquette.....	750	10		51	44			105	14	83	248
Milwaukee.....	513	41	3	264		51.6	211	370.6	72.2	138.6	92
Monroe.....	1,302	30	10	19	35	.1		95	7.29	34	524
Oconto.....	1,040	14		164	32			210	20.19	43	397
Oncida.....	708			5	18			23	3.24	23	374
Outagamie.....	1,147	38	2	240	35		9	324	28.2	65	469
Ozaukee.....	496	10		376				386	81.45	61	54
Pepin.....	417			5	29			34	8.15	17	176
Pierce.....	1,232	1		57	29			87	7.06	56	487
Polk.....	1,614			45	29			74	4.58	39	857
Portage.....	1,364	30	4	29	24			87	6.37	1	594
Price.....	794			9				9	1.13	32	493
Racine.....	606	18	4	274		4		300	49.5	56	195
Richland.....	1,191.2	19		18	18	.2		55.2	4.63	5.8	513
Rock.....	1,296	76		467	30			573	44.21	251	407
Rusk.....	808			19	4			23	2.84	1	491
St. Croix.....	1,398			187	10			197	14.09	87	776
Sauk.....	1,502	113		66	64	.3		243.3	16.19	178.3	586
Sawyer.....	565			10	10			10	1.77	4	274
Shawano.....	1,411	8		164	57			229	16.2	119	700
Sheboygan.....	1,130.2	10		439	24	3.2		476.2	42.1	173.8	392
Taylor.....	867			36	28			64	7.38	6	529
Trempealeau.....	1,239	11	6	29	59			105	8.47	21	735
Vernon.....	1,554	8		12	4			24	1.54	28	843
Vilas.....	410			10	10			20	4.87	20	237
Walworth.....	1,076	34	4	423	37			498	46.2	140	341
Washburn.....	1,021				5			5	.48	29	506
Washington.....	946	7		531	15			553	58.4	18	254
Waukesha.....	1,120	71		572				643	57.4	67	268
Waupaca.....	1,487	16		203	86			305	20.5	162	578
Waushara.....	1,319	25	6	76	74			181	13.7	112	465
Winnebago.....	1,848.2	13	8	491	25	1.2		538.2	63.4	46.8	161
Wood.....	1,182	11		5	7			23	1.94	16	645
Total.....	75,706.67	1,408	183	9,597	2,054	83.07	74.4	13,399.47	17.6	3,232.14	30,927

¹ Includes .4 mile surfaced with brick.² Includes 2 miles surfaced with brick.

WYOMING.

TABLE 29.—*Mileage of public roads outside of incorporated cities and towns, 1914.*

County.	Total mileage of all roads.	Surfaced roads.			Graded and drained earth.
		Total of surfaced roads. ¹	Percent- age of roads surfaced.	Increase in sur- faced mileage over 1909.	
Albany.....	989	9	0.91	9	70
Bighorn.....	340				10
Campbell.....	600				
Carbon.....	760				10
Converse.....	656	26	3.96	26	30
Crook.....	1,550				50
Fremont.....	600				25
Goshen.....	500				25
Hot Springs.....	150				100
Johnson.....	1,122	2	.17	2	20
Laramie.....	2,020				20
Lincoln.....	740	10	1.35	10	130
Natrona.....	281	5	1.77	5	08
Niobrara.....	350				
Park.....	840	.5	.05	.5	340
Platte.....	650				250
Sheridan.....	614				250
Sweetwater.....	562				196
Uinta.....	497				43
Washakie.....	250				25
Weston.....	310				10
Total.....	14,381	52.5	.36	52.5	1,672
Yellowstone National Park.....	416	416	100		
Grand total.....	14,797	468.5	3.1	52.5	1,672

¹ All gravel.

APPENDIX B.

The following are the tables referred to in the foregoing text giving information as to revenues applied to roads in the States discussed:

ARIZONA.

TABLE 30.—*Revenue applied to roads and bridges, 1914.*

County.	Total revenue applied to roads and bridges.	General county road and bridge tax.		Other revenue applied to roads.	
		Rate, cents per \$100.	Amount.	Amount.	Source.
Apache.....	\$12,212.00	15	\$9,354.00	\$2,000.00	Forest-reserve fund.
Cochise.....	107,024.16	10	93,744.87	858.00	Per capita tax.
Cocconino.....	48,861.06	7	12,036.06	13,279.29	Do.
Gila.....	48,369.81	10.7	38,815.81	35,955.00	Balance from 1914.
Graham.....	12,467.99	9.6	10,000.00	870.00	Per capita tax.
Greenlee.....	66,362.51	19	58,754.51	9,554.00	Do.
Maricopa.....	106,592.98	13.5	102,920.98	1,859.99	Forest appropriation and miscellaneous receipts.
Mohave.....	22,313.49	13	19,873.49	608.00	Per capita tax.
Navajo.....	17,759.63	23	17,371.63	7,608.00	Do.
Pima.....	36,614.13	14	35,837.86	3,672.00	Do.
Pinal.....	42,574.30	14.3	34,806.80	2,440.00	Do.
Santa Cruz.....	9,205.93	11	7,011.98	388.00	Do.
Yavapai.....	67,228.53	14.5	63,038.53	498.27	Forest receipts.
Yuma.....	20,457.92	14.2	19,547.92	278.00	Per capita tax.
				7,767.50	Do.
				1,155.95	Forest-reserve fund.
				1,038.00	Per capita tax.
				4,190.00	Do.
				910.00	Do.
Total.....	618,044.44	.....	523,114.44	94,930.00	
	1355,896.19				
	2 8,780.59				
Grand total	982,721.22				

¹ Expenditures from State fund for fiscal year ended June 30, 1914, including motor-vehicle revenue.

² Expenditures from county bond issue funds.

CALIFORNIA.

TABLE 31.—Revenue applied to roads and bridges for the fiscal year ended June 30, 1915.

County.	Total.	County expenditures on highways.	County expenditures on bridges.
Alameda.....	\$319,532.48	\$263,106.33	\$56,426.15
Alpine.....	554.22	554.22	.....
Amador.....	24,349.47	20,342.74	4,006.73
Butte.....	207,839.07	99,707.86	108,131.21
Calaveras.....	34,990.07	34,990.07	.....
Colusa.....	261,897.44	94,550.04	167,347.40
Contra Costa.....	201,562.27	187,960.37	13,601.90
Del Norte.....	41,184.94	25,886.78	15,298.16
El Dorado.....	37,257.12	24,088.71	13,168.41
Fresno.....	441,853.92	391,909.46	49,944.46
Glenn.....	170,850.20	117,805.86	53,044.34
Humboldt.....	356,024.67	199,498.79	156,525.88
Imperial.....	181,471.43	160,555.84	20,915.59
Inyo.....	29,551.48	22,806.84	6,744.64
Kern.....	470,628.04	464,242.24	6,385.80
Kings.....	68,633.63	68,439.23	194.40
Lake.....	38,199.14	24,598.99	13,600.15
Lassen.....	39,577.52	39,577.52	.....
Los Angeles.....	2,004,577.94	1,771,504.08	233,073.86
Madera.....	137,516.57	45,370.57	92,146.00
Marin.....	96,665.14	63,246.14	33,419.00
Mariposa.....	27,385.10	16,584.58	10,801.12
Mendocino.....	188,790.86	126,350.52	62,440.34
Merced.....	200,060.72	141,576.86	58,483.86
Modoc.....	23,741.83	24,941.83	800.00
Mono.....	7,732.73	5,582.73	2,150.00
Monterey.....	247,382.97	141,608.75	105,774.22
Napa.....	112,566.22	83,944.39	28,621.83
Nevada.....	33,838.02	28,383.13	5,454.89
Orange.....	911,725.44	855,707.33	56,018.11
Placer.....	64,285.15	41,829.36	22,455.79
Plumas.....	39,894.09	24,479.14	15,414.95
Riverside.....	414,801.96	401,605.89	13,196.07
Sacramento.....	344,175.48	174,471.11	169,704.37
San Benito.....	74,474.89	40,963.91	33,510.98
San Bernardino.....	275,756.94	260,761.59	14,995.35
San Diego.....	254,358.76	233,048.20	21,310.56
San Joaquin.....	273,054.89	259,824.09	13,230.80
San Luis Obispo.....	233,236.89	86,358.04	146,878.85
San Mateo.....	945,991.39	909,092.87	36,898.52
Santa Barbara.....	267,360.35	188,486.02	78,874.33
Santa Clara.....	341,462.20	327,686.20	13,776.00
Santa Cruz.....	123,110.61	95,349.96	29,760.65
Shasta.....	99,010.97	54,678.46	44,332.51
Sierra.....	28,649.13	22,808.02	5,841.11
Siskiyou.....	36,013.03	25,491.53	10,521.50
Solano.....	85,142.08	68,430.17	16,711.91
Sonoma.....	204,383.10	163,956.13	40,426.97
Stanislaus.....	151,524.14	98,020.00	53,504.14
Sutter.....	125,504.48	42,480.88	83,023.60
Tehama.....	138,601.82	92,778.15	45,823.67
Trinity.....	30,287.93	24,426.12	5,861.81
Tulare.....	297,385.37	262,496.45	34,888.92
Tuolumne.....	80,515.14	61,524.65	18,990.49
Ventura.....	210,136.97	131,127.10	79,009.87
Yolo.....	175,235.55	109,168.82	66,066.73
Yuba.....	85,092.49	43,472.76	41,619.73
Total.....	12,321,387.05	9,790,238.42	2,531,148.63
Expenditures for State roads and State highways.....	6,850,597.61	.....	.....
Grand total.....	119,171,984.66	.....	.....

¹ Exclusive of San Francisco County which is coextensive with the city of San Francisco.

COLORADO.

TABLE 32.—Revenue applied to roads and bridges, 1914.

County.	Total revenue applied to roads and bridges. ¹	General county road and bridge tax.		Received from motor vehicle licenses.	State expenditure.	Received from forest reserve fund.
		Rate, mills per \$1.	Amount.			
Adams.....	\$42,005.03	1.5	\$33,451.69	\$423.90	\$8,129.44	.....
Alamosa.....	11,778.95	1.5	10,055.13	244.38	1,479.44	.....
Arapahoe.....	26,378.05	1.25	20,737.74	420.60	5,219.71	.....
Archuleta.....	16,892.18	3	13,103.06	47.64	1,000.00	\$2,741.48
Baca.....	2,939.40	.40	947.71	58.38	1,933.31	.....
Bent.....	18,443.28	1.34	15,092.65	365.66	2,984.97	.....
Boulder.....	78,859.59	1.64	65,666.40	1,604.79	11,348.50	239.90
Chaffee.....	20,500.57	1.26	14,701.74	372.84	3,828.25	1,597.74
Cheyenne.....	4,923.79	.50	3,861.80	61.99	1,000.00	.....
Clear Creek.....	14,597.84	2	10,538.60	110.84	3,558.18	390.22
Conejos.....	11,759.06	1.19	9,768.14	148.55	468.37	1,374.00
Costilla.....	15,597.26	2.45	13,404.56	87.43	2,054.57	50.70
Crowley.....	12,944.16	1.30	10,851.34	201.96	1,890.86	.....
Custer.....	8,303.43	2.50	6,457.45	60.21	1,463.97	321.80
Delta.....	33,058.02	2	30,232.67	400.91	1,500.00	924.44
Dolores.....	6,750.20	2.4	3,619.77	1.00	1,031.95	2,097.48
Douglas.....	43,036.27	1.8	17,270.28	139.11	25,212.27	414.61
Eagle.....	23,642.20	1.8	11,710.28	86.45	8,057.71	3,787.76
Elbert.....	20,135.60	1.7	17,621.73	125.61	2,388.26	.....
El Paso.....	74,145.19	.9	62,474.43	3,343.95	8,000.00	326.81
Fremont.....	60,892.30	2	40,221.67	769.61	19,783.02	118.00
Garfield.....	71,687.97	3.4	63,666.31	301.14	5,500.00	2,220.52
Gilpin.....	11,143.03	3	11,036.51	4.09	.....	102.43
Grand.....	13,499.90	1.75	8,937.45	63.96	1,418.47	3,080.02
Gunnison.....	39,720.93	2.3	33,646.77	165.90	2,500.00	3,408.26
Hinsdale.....	6,158.20	3	2,730.93	4.61	1,000.00	2,422.66
Huerfano.....	6,648.72	.5	6,118.44	229.88	.....	300.40
Jackson.....	13,254.44	2	7,898.03	43.72	2,884.64	2,428.05
Jefferson.....	54,006.75	2.25	46,207.23	455.62	7,100.00	243.90
Kiowa.....	5,136.37	.55	3,901.32	106.02	1,129.03	.....
Kit Carson.....	11,182.37	.9	9,023.13	159.24	2,000.00	.....
Lake.....	15,706.38	.48	6,569.22	167.50	8,433.40	536.26
La Plata.....	47,779.18	2.5	38,627.33	262.97	7,214.56	1,674.32
Larimer.....	111,085.29	2.55	87,922.49	2,164.93	20,026.90	970.97
Las Animas.....	47,818.67	1	39,493.96	649.62	7,631.29	43.80
Lincoln.....	15,206.61	1.2	11,975.41	181.98	3,049.22	.....
Logan.....	39,671.65	2	37,217.43	658.42	1,795.80	.....
Mesa.....	49,707.86	1.53	43,161.32	698.97	3,500.00	2,347.57
Mineral.....	7,925.24	1.9	3,267.01	16.69	2,004.41	2,637.13
Moffat.....	17,554.35	2	8,323.00	68.23	8,838.13	324.99
Montezuma.....	23,825.03	3	18,787.47	124.31	3,223.03	1,690.22
Montrose.....	50,345.48	3.1	45,112.69	353.76	3,500.00	1,379.03
Morgan.....	53,381.64	2.9	48,860.99	575.52	3,945.13	.....
Otero.....	74,590.87	2.55	71,155.27	944.45	2,491.15	.....
Ouray.....	17,279.16	2.5	14,326.19	63.48	2,290.98	598.51
Park.....	23,989.13	2	18,003.29	125.87	3,885.04	1,974.93
Phillips.....	5,987.76	.7	5,158.22	295.72	533.82	.....
Pitkin.....	20,065.24	1	6,912.52	30.61	11,010.38	2,111.73
Prowers.....	37,671.03	1.8	33,748.84	422.19	3,500.00	.....
Pueblo.....	102,697.12	1.4	92,078.47	2,122.26	8,424.86	71.53
Rio Blanco.....	23,270.77	2.66	12,859.96	65.81	8,861.45	1,483.55
Rio Grande.....	38,097.29	2	20,925.16	367.71	15,650.77	1,153.65
Routt.....	40,335.47	2.69	33,532.52	89.60	3,941.62	2,771.73
Saguache.....	37,063.95	2.8	32,519.12	224.09	1,750.82	2,569.92
San Juan.....	11,204.67	2	9,491.15	5.51	1,101.91	606.10
San Miguel.....	39,350.39	4	37,236.48	48.96	861.75	1,203.20
Sedgwick.....	14,006.10	2.1	12,333.39	172.71	1,500.00	.....
Summit.....	20,763.51	3	17,457.68	22.38	2,000.00	1,283.45
Teller.....	22,612.58	1.34	21,527.23	496.52	271.75	317.08
Washington.....	11,694.03	1	10,840.74	190.95	662.34	.....
Weld.....	108,854.91	1.3	99,327.55	2,441.18	7,086.18	.....
Yuma.....	11,326.32	1	9,948.85	377.47	1,000.00	.....
Total.....	1,920,888.73	.....	1,553,655.91	25,040.36	285,851.61	56,340.85
	² 15,423.00	.....	.....	.....	.....	.....
	³ 1,234.50	.....	.....	.....	.....	.....
Grand total.....	1,937,546.23	.....	.....	.....	.....	.....

¹ Exclusive of Denver County, which is coextensive with the city of Denver.² State appropriation for administration of State highway department.³ Expended from bond-issue fund in Garfield County.

IDAHO.

TABLE 33.—Revenue applied to roads and bridges, 1914.

County.	Total revenue applied to roads and bridges.	General county road and bridge tax.		Other revenue applied to roads and bridges.	
		Rate, mills per \$1.	Amount.	Amount.	Source.
Ada.....	\$41,664.95	7	\$29,635.78	{ \$6,973.00 5,056.17	Auto license. Special highway tax.
Adams ¹					
Bannock.....	49,071.03	1.5	37,301.51	11,769.52	Road poll tax.
Bear Lake.....	12,626.03	.8	11,251.03	1,375.00	Auto licenses.
Bingham.....	46,399.71		42,356.21	{ 2,871.50 1,172.00	Road poll tax. Miscellaneous revenue.
Blaine.....	26,134.00	.6	26,134.00		
Boise.....	25,812.62		25,812.62		
Bonner.....	98,094.02	3	78,600.00	{ 12,000.00 1,000.00 494.02 6,000.00	Forest department lumber sale. Auto licenses. Special highway tax. Saloon licenses.
Bonneville.....	7,400.00	2.5	7,400.00		
Canyon.....	58,539.48	1	24,222.76	34,316.72	Special road levy.
Cassia.....	16,647.43	2.5	16,647.43		
Clearwater.....	26,365.35	2.5	22,500.00	{ 2,065.35 1,570.00	Special highway tax. Special road tax.
Custer.....	16,421.51	.35	11,721.87	3,329.64	Forest-reserve apportionments.
Elmore.....	15,461.89	.23	15,461.89		
Franklin.....	19,154.90	2.5	^a 16,552.13	{ 693.52 1,802.25 102.00	Forest-reserve apportionments. Motor vehicle tax. Miscellaneous revenue.
Fremont.....	15,944.03	.7	15,944.03		
Gooding.....	34,220.43	.6	21,783.60	12,436.83	Special highway tax.
Idaho.....	58,816.31	1	11,600.01	47,216.30	Special district levies.
Jefferson.....	5,257.00	5	3,250.00	1,806.00	Road poll tax.
Kootenai.....	101,419.56	3.5	86,970.95	14,448.61	Special highway tax.
Latah.....	62,174.68	1.6	33,363.40	28,811.28	Special road tax.
Lemhi.....	21,840.37	.3	15,278.32	{ 2,051.80 1,416.00	Forest-reserve apportionments. Road poll tax.
Lewis.....	22,339.50	1.8		3,094.25	Unredeemed warrants.
Lincoln.....	37,160.42		15,000.00	7,339.50	Special highway tax.
Madison.....	4,000.00	.3	21,021.60	{ 15,514.82 624.00	Do. Road poll tax.
Minidoka.....	11,500.00	.7	3,000.00	1,000.00	Do.
Nez Perce.....	53,633.72	2	4,000.00	7,500.00	Miscellaneous revenue.
Oneida.....	13,700.00	.3	32,757.00	20,876.72	Special highway tax.
Power.....	24,300.00	3	12,500.00	1,200.00	Auto licenses.
Shoshone.....	75,037.50	2	24,300.00	{ 12,888.45 5,064.00 5,021.08 13,586.86	Road poll tax. State and county licenses. Forest-reserve apportionments. Miscellaneous revenue.
Twin Falls....	60,992.75	2.5	39,216.62	{ 4,594.80 2,766.79	Auto licenses. Road poll tax.
Washington...	35,528.28	3.1	32,541.00	{ 14,414.54 1,977.00 1,010.28	Special highway tax. Road poll tax. Special highway tax.
Total....	1,095,656.47 ^a 226,000.00 ⁴ 49,812.12		776,600.87	319,055.60	
Grand total..	1,371,468.59				

¹ No report.² Includes poll tax.³ County and district road and bridge bonds.⁴ State expenditures on highways.

ILLINOIS.

TABLE 34.—Revenue applied to roads and bridges, 1914.

County.	Total revenue applied to roads and bridges.	Amounts obtained from general county and township tax.	Other revenue applied to roads.	
			Amount.	Source.
Adams.....	\$113,985.05	\$75,985.05	\$38,000.00	State and county appropriation.
Alexander.....	80,314.07	80,314.07		
Bond.....	33,493.45	33,493.45		
Boone.....	60,127.00	50,127.00	10,000.00	County board appropriation.
Brown.....	23,000.00	23,000.00		
Bureau.....	117,700.50	114,000.00	3,700.50	Special township tax.
Calhoun.....	15,117.00	14,000.00	1,117.00	State aid.
Carroll.....	69,779.05	69,779.05		
Cass.....	45,000.00	45,000.00		
Champaign.....	160,000.00	160,000.00		
Christian.....	107,426.89	107,426.89		
Clark.....	94,245.11	43,340.23	50,904.88	Hard-road levies.
Clay.....	29,969.00	23,926.00	3,731.00	B. and O. appropriation.
Clinton.....	33,768.84	33,768.84	2,312.00	Cash poll tax.
Coles.....	72,257.72	72,257.72		
Cook.....	418,194.00	200,000.00	134,000.00	State aid.
Crawford.....	110,887.00	54,130.60	79,194.00	Special hard-road tax.
Cumberland.....	32,669.61	29,570.61	5,000.00	County fund for highway superintendents.
Dekalb.....	130,851.00	113,900.00	56,756.40	Hard-road tax.
Dewitt.....	58,385.05	58,385.05	3,099.00	State aid.
Douglas.....	100,030.89	65,953.96	16,951.00	Special taxes and damages.
Dupage.....	100,161.40	91,888.54	34,076.93	Special township tax for hard roads.
Edgar.....	205,458.11	85,797.20	8,272.86	Special township hard-road tax.
Edwards.....	12,000.00	12,000.00	116,660.91	Hard-road tax.
Efingham.....	36,743.40	36,743.40	3,000.00	County bridge money.
Fayette.....	28,587.91	13,187.91	7,700.00	State aid.
Ford.....	70,099.50	65,300.00	7,700.00	County appropriation.
Franklin.....	47,899.52	47,899.52	4,799.50	Special gravel tax.
Fulton.....	101,681.66	100,221.66	1,460.00	Poll tax from townships.
Gallatin.....	17,523.23	17,523.23		
Greene.....	48,178.33	46,057.33	2,121.00	County appropriation to three townships.
Grundy.....	55,275.00	55,275.00		
Hamilton.....	24,637.00	21,637.00	3,000.00	Cash poll tax.
Hancock.....	85,683.98	85,683.98		
Hardin.....	4,283.50	4,120.44	163.06	County dog-tax appropriation.
Henderson.....	39,451.26	38,779.41	671.85	Cash poll tax.
Henry.....	100,680.30	100,680.30		
Iroquois.....	177,689.58	164,345.52	13,344.06	Hard-road tax.
Jackson.....	50,202.76	43,327.76	6,875.00	Special levy fund.
Jasper.....	33,831.84	33,831.84		
Jefferson ¹	39,606.02	39,606.02		
Jersey.....	25,490.43	24,362.86	1,127.57	Road and ditch damages.
Jo Daviess.....	66,876.47	63,656.00	1,613.49	Road and bridge drainage rates.
Johnson.....	15,532.00	15,532.00	1,606.98	Road and bridge special tax.
Kane.....	120,514.97	118,000.72	2,514.25	Special hard-road tax.
Kankakee.....	122,409.34	77,319.15	32,983.31	Hard-road tax.
Kendall.....	52,521.29	37,542.02	12,106.83	Refund railroad-bond tax.
Knox.....	86,494.44	84,371.49	11,479.46	Special gravel tax.
Lake.....	152,221.73	112,343.63	3,499.81	New road damages and poll tax
La Salle.....	241,864.00	208,974.00	2,122.95	Road and ditch damages.
Lawrence.....	111,150.71	57,611.00	39,878.10	Special township gravel tax.
Lee.....	89,357.00	89,357.00	32,890.00	Hard-road township tax.
Livingston.....	138,959.00	138,959.00	6,600.00	State aid.
Logan.....	90,886.62	90,886.62	46,939.71	Special road tax.
McDonough.....	65,651.00	65,651.00		
McHenry.....	122,607.33	95,607.33	27,000.00	State aid.
McLean.....	212,330.66	212,330.66		
Macon ¹	128,939.83	128,939.83		
Macoupin.....	89,600.70	89,600.70		
Madison.....	167,710.66	126,026.96	41,683.70	Special township tax levy.
Marion.....	61,810.43	44,873.88	7,084.00	State aid.
Marshall.....	49,495.00	49,495.00	9,852.55	County appropriation.
Mason.....	44,148.00	44,148.00		
Massac.....	26,224.12	26,224.12		

ILLINOIS—Continued.

TABLE 34.—Revenue applied to roads and bridges, 1914—Continued.

County.	Total revenue applied to roads and bridges.	Amounts obtained from general county and township tax.	Other revenue applied to roads.	
			Amount.	Source.
Menard.....	\$32,653.60	\$29,016.60	\$3,637.00	State aid.
Mercer.....	64,389.43	64,389.43		
Monroe.....	28,331.61	24,660.00	{ 2,667.00	Poll tax.
Montgomery...	84,337.59	84,337.59	{ 1,004.61	Donated by county.
Morgan.....	77,980.26	77,980.26		
Moultrie.....	41,779.12	41,779.12		
Ogle.....	125,630.00	125,630.00		
Peoria.....	168,054.60	168,054.60		
Perry.....	37,906.40	37,906.40		
Piatt.....	62,805.63	62,805.63		
Pike.....	57,875.80	57,875.80		
Pope.....	14,565.00	11,025.00	3,540.00	Poll tax.
Pulaski.....	12,883.00	9,642.00	3,241.00	Special hard-road tax.
Putnam ¹	19,981.93	19,981.93		
Randolph.....	45,238.90	45,238.90		
Richland ¹	25,788.92	25,788.92		
Rock Island....	47,100.41	38,147.55	{ 6,854.96	Railway tax.
St. Clair.....	89,681.00	86,911.00	{ 2,097.90	Special hard-road tax.
Saline.....	65,402.35	65,402.35	{ 2,770.00	Special township taxes.
Sangamon.....	142,641.98	142,641.98		
Schuyler.....	37,183.27	37,183.27		
Scott.....	33,720.00	33,720.00		
Shelby.....	98,485.39	98,485.39		
Stark.....	43,875.00	43,875.00		
Stephenson....	95,728.00	75,032.00	{ 10,348.00	State aid.
Tazewell.....	87,227.00	87,227.00	{ 10,348.00	County appropriation.
Union.....	28,250.00	28,250.00		
Vermilion.....	191,843.00	191,843.00		
Wabash ¹	21,996.02	21,996.02		
Warren.....	74,619.59	74,619.59		
Washington....	44,250.00	35,000.00	{ 4,850.00	County appropriation for bridges.
Wayne.....	361,600.00	361,600.00	{ 4,400.00	Township hard roads.
White.....	54,265.00	37,400.00	{ 4,165.00	Poll tax.
Whiteside.....	94,912.00	94,912.00	{ 12,700.00	Special hard-road tax.
Will.....	202,485.40	202,485.40		
Williamson ¹ ...	42,048.59	42,048.59		
Winnebago.....	137,741.23	137,741.23		
Woodford.....	54,642.08	54,642.08		
Total.....	8,419,570.36	7,451,353.18	968,217.18	
	² 106,287.00			
	³ 208,855.41			
Grand total.	8,734,712.77			

¹ For 1913; information not available for 1914.² Expended from State appropriation for administration, engineering, and miscellaneous equipment by State highway department.³ Expended from local bond funds.

INDIANA.

TABLE 35.—Revenue applied to roads and bridges, 1914.

County.	Total revenue applied to roads.	General county tax for road repairs.		Road tax. ¹	Additional road tax.	Receipts from motor vehicle licenses.	Statute labor, cash value.
		Rate, cents per \$100.	Amount.				
Adams.....	\$52,237.95	.199	\$32,251.96	\$3,271.35	\$7,725.42	\$5,816.10	\$3,173.12
Allen.....	134,601.05	.06	38,092.49	27,866.38	25,671.26	10,341.45	32,629.47
Bartholomew.....	62,363.61	.15	30,167.19	12,436.39	.....	5,373.27	14,386.76
Benton.....	56,113.68	.10	20,675.70	17,576.92	.....	6,310.12	11,550.94
Blackford.....	36,989.22	.20	20,309.38	8,809.52	.....	3,850.92	4,019.40
Boone.....	90,703.06	.16	49,517.76	19,105.28	.....	6,714.09	15,365.93
Brown.....	9,693.49	.03	691.82	1,503.49	1,975.22	1,859.73	3,663.23
Carroll.....	52,998.59	.159	22,754.18	11,756.45	.....	5,473.27	13,014.69
Cass.....	75,917.95	.14	29,148.53	12,522.57	10,261.04	7,189.94	16,795.87
Clark.....	38,490.97	.12	17,041.23	6,558.71	6,293.43	3,113.03	5,484.57
Clay.....	33,986.56	.12	19,171.61	8,582.74	.....	4,572.74	1,659.47
Clinton.....	13,673.42	.10	.....	3,100.23	.....	9,406.30	1,166.89
Crawford.....	9,919.13	.07	1,862.71	1,657.63	967.92	1,999.64	3,431.23
Daviess.....	44,096.23	.20	28,692.81	8,119.46	.....	3,194.04	4,089.92
Dearborn.....	31,945.92	.059	6,000.24	11,654.44	422.02	2,657.06	11,212.16
Decatur.....	59,716.59	.204	33,847.97	11,642.87	.....	4,661.52	9,564.23
Dekalb.....	55,491.22	.....	.....	18,631.06	11,609.57	3,689.95	21,560.64
Delaware.....	75,789.99	.069	22,145.30	26,840.27	.....	6,820.48	19,983.94
Dubois.....	20,038.33	.079	6,972.93	6,934.83	.....	2,466.09	3,664.48
Elkhart.....	52,747.85	.....	.....	14,554.36	11,891.01	5,954.14	20,348.34
Fayette.....	29,916.42	.005	621.93	11,940.91	.....	3,032.79	14,320.79
Floyd.....	11,819.83	.02	2,437.16	4,060.78	.....	2,360.54	2,961.35
Fountain.....	64,510.63	.15	22,827.18	7,551.91	11,108.26	4,911.49	18,111.79
Franklin.....	41,136.91	.135	12,646.85	3,042.26	6,571.58	3,265.26	15,610.96
Fulton.....	49,651.15	.059	7,757.34	20,332.93	.....	3,523.75	18,037.13
Gibson.....	48,146.28	.10	18,660.78	11,307.98	10,187.95	3,716.54	4,273.03
Grant.....	112,948.02	.30	91,404.13	6,248.00	.....	9,093.55	6,202.34
Greene.....	72,205.91	.309	47,285.08	4,144.08	11,135.99	5,197.82	4,442.94
Hamilton.....	82,313.08	.25	51,239.41	4,796.92	12,955.03	7,244.35	6,077.37
Hancock.....	70,003.30	.129	24,609.83	21,892.49	.....	4,480.92	19,020.06
Harrison.....	25,167.55	.14	8,944.31	3,446.41	3,930.36	2,724.96	6,121.51
Hendricks.....	68,115.09	.08	15,606.59	12,441.73	14,799.76	4,314.34	20,952.67
Henry.....	83,703.65	.11	27,359.64	25,819.87	.....	5,377.43	25,146.71
Howard.....	45,933.18	.099	22,672.27	9,786.82	.....	7,301.95	6,172.14
Huntington.....	78,833.34	.159	34,400.71	19,388.21	.....	6,526.82	18,517.61
Jackson.....	42,926.13	.20	30,511.30	4,591.71	.....	5,647.39	2,175.73
Jasper.....	51,292.75	.125	15,775.16	10,102.76	9,408.01	4,019.35	11,987.47
Jay.....	68,128.52	.13	22,085.78	13,430.46	12,419.46	5,488.75	14,704.07
Jefferson.....	31,722.26	.16	14,876.58	2,569.46	3,495.67	3,041.25	7,739.31
Jennings.....	28,920.21	.159	10,192.37	4,867.84	4,127.08	3,340.80	6,392.11
Johnson.....	57,912.00	.149	27,511.97	4,287.55	8,816.70	4,493.73	12,802.05
Knox.....	58,407.24	.15	39,038.75	939.06	11,750.89	6,431.19	247.35
Kosciusko.....	65,199.99	.01	2,370.42	17,134.72	12,038.99	3,859.38	29,796.48
Lagrange.....	31,894.58	.....	.....	6,860.66	9,539.04	3,234.69	12,260.19
Lake.....	128,883.51	.10	72,533.47	47,054.41	.....	9,295.63	.....
Laporte.....	74,881.34	.10	35,518.52	16,847.75	10,785.06	5,442.21	6,287.80
Lawrence.....	46,384.45	.25	35,098.59	5,162.56	581.56	5,292.05	249.69
Madison.....	77,237.09	.10	36,661.67	19,269.72	.....	9,849.28	11,457.02
Marion.....	182,201.20	.044	115,346.59	11,843.62	22,768.08	22,138.91	10,104.00
Marshall.....	44,131.03	.01	1,867.02	12,574.24	9,420.27	3,679.17	16,590.33
Martin.....	17,578.60	.10	4,433.42	5,754.08	.....	2,271.40	5,119.70
Miami.....	58,845.14	.10	19,254.38	11,349.03	10,190.96	5,657.71	12,393.06
Monroe.....	38,298.97	.25	26,491.19	3,441.27	684.07	4,191.79	3,490.65
Montgomery.....	50,074.14	.1075	.....	24,758.48	.....	7,190.94	18,124.72
Morgan.....	47,526.85	.11	14,637.34	28,890.04	.....	3,999.47	.....
Newton.....	55,191.21	.20	27,103.28	14,229.49	.....	4,845.98	9,012.46
Noble.....	48,697.26	.....	.....	16,296.17	10,765.62	3,447.84	18,187.63
Ohio.....	14,441.64	.40	8,023.31	389.27	1,339.70	2,105.77	2,583.59
Orange.....	33,683.84	.27	17,191.47	9,483.23	.....	3,655.89	3,353.25
Owen.....	32,105.28	.23	15,455.61	7,261.82	.....	3,296.31	6,091.54
Parke.....	53,104.07	.25	36,811.05	6,283.72	.....	6,542.98	3,466.32
Perry.....	12,057.52	.02	803.86	3,460.56	387.98	1,828.42	5,576.70
Pike.....	21,775.90	.07	5,012.25	3,268.25	5,669.58	2,387.89	5,437.93
Porter.....	72,517.14	.20	44,193.50	6,732.46	15,507.17	4,617.72	1,466.29
Posey.....	39,682.80	.12	18,478.76	4,665.78	10,362.15	3,514.87	2,661.24
Pulaski.....	38,011.40	.109	10,292.11	7,190.23	7,789.21	4,094.90	8,644.95
Putnam.....	62,332.93	.2465	43,658.08	3,971.79	2,308.94	7,347.27	5,046.85
Randolph.....	81,803.51	.15	34,920.07	7,387.27	17,572.86	6,390.55	15,532.76
Ripley.....	39,909.49	.20	15,480.90	9,518.27	.....	3,718.78	11,191.54

¹ This includes township tax, road tax, and work road tax which is paid in cash; the township tax rate varies in every county and in every township in the county.

INDIANA—Continued.

TABLE 35.—Revenue applied to roads and bridges, 1914—Continued.

County.	Total revenue applied to roads.	General county tax for road repairs.		Road tax. ¹	Additional road tax.	Receipts from motor vehicle licenses.	Statute labor, cash value.
		Rate, cents per \$100.	Amount.				
Rush.....	\$78,274.68	.12	\$25,084.19	\$25,056.62	.....	\$5,078.78	\$23,055.09
St. Joseph.....	54,411.67	.02	9,982.52	17,716.27	\$9,827.31	6,982.73	9,902.84
Scott.....	17,344.03	.14	5,353.03	2,821.78	2,235.76	2,633.74	4,299.72
Shelby.....	72,562.50	.09	21,310.96	6,920.03	14,868.57	5,079.48	24,383.46
Spencer.....	34,028.37	.....	13,542.54	10,393.92	.....	2,060.01	8,031.90
Starke.....	52,599.36	.30	24,556.45	13,686.05	6,840.77	3,914.50	3,601.59
Steuben.....	31,534.91	.....	.....	17,800.58	.....	3,174.81	10,559.52
Sullivan.....	72,497.40	.20	38,640.03	5,215.69	19,866.21	5,461.35	3,314.12
Switzerland.....	14,341.09	.125	4,184.93	4,118.66	.....	2,672.94	3,364.56
Tippecanoe.....	67,308.60	.089	32,252.80	5,777.29	9,978.33	8,799.23	10,500.95
Tipton.....	30,106.15	.16	23,422.31	.36	.62	6,682.86	.....
Union.....	28,992.13	.10	6,651.43	4,142.60	5,547.22	2,947.89	9,702.99
Vanderburg.....	52,451.48	.055	27,633.26	5,855.76	9,743.76	5,592.63	3,626.07
Vermilion.....	45,972.53	.2215	31,625.76	9,349.63	25.51	4,868.88	102.75
Vigo.....	63,633.68	.06	32,224.28	20,340.02	.....	7,140.98	3,928.40
Wabash.....	68,430.50	.129	27,175.21	21,565.09	.....	5,986.26	13,703.94
Warren.....	47,121.30	.15	20,008.55	13,641.48	.....	4,742.12	8,729.15
Warrick.....	20,674.72	.02	1,702.19	2,892.66	6,633.44	2,183.54	7,262.89
Washington.....	41,018.01	.20	16,704.56	6,276.45	3,531.86	3,459.31	11,045.83
Wayne.....	80,485.74	.07	24,408.41	28,394.79	.....	6,387.25	21,295.29
Wells.....	51,149.60	.24	42,221.14	258.38	1,289.55	7,380.53	.....
White.....	59,492.64	.15	22,511.74	31,555.93	.....	5,424.97	.....
Whitley.....	53,688.12	.01	1,475.16	13,665.25	11,351.80	3,259.64	23,936.27
Total.....	4,837,798.95 ² 8,989,570.98 ³ 406,616.00	.....	2,022,117.24	1,018,639.26	446,975.58	462,811.08	887,255.79
Grand total	14,233,985.93						

¹ This includes township tax, road tax, and work road tax which is paid in cash; the township tax rate varies in every county and in every township in the county.

² Expended from township bonds.

³ Expended from county bonds.

TABLE 36.—Revenue applied to roads and bridges, 1914.

County.	Total revenue applied to roads and bridges.	General county and township tax.		Other revenues applied to roads.			Statute labor revenue.		
		Bridge revenue.	Road revenue.	Source.		Number of men who worked out labor tax.	Average number of days worked.	Daily statute wage.	Cash value statute labor.
				Township drag tax.	Motor tax.	Poll tax. ¹			
Adair.....	\$94,321.30	\$32,832.85	\$28,136.83	\$18,589.02	\$9,753.60	\$1,819.00	638	\$2.50	\$3,190.00
Adams.....	65,960.77	27,791.75	27,194.24	3,751.12	5,832.16	1,391.50	2	2.50	3,245.00
Allamakee.....	89,886.24	\$35,022.35	35,566.65	5,400.50	8,778.24	2,173.50	2	2.50	2,100.00
Appanoose.....	75,655.31	26,713.81	26,078.20	5,927.35	5,852.16	1,445.50	420	2.50	2,630.00
Audubon.....	86,744.37	33,269.05	37,620.31	10,327.34	9,753.60	3,212.00	2	2.50	3,440.00
Benton.....	147,568.27	32,009.60	58,825.73	23,912.15	8,778.24	6,126.50	688	2.50	2,855.00
Black Hawk.....	111,597.92	32,371.79	37,554.24	15,921.26	8,290.56	3,379.00	571	2.50	2,905.00
Boone.....	96,771.44	30,677.22	35,598.40	5,724.62	6,827.52	2,025.50	2	2.50	3,685.00
Bremer.....	83,683.77	37,330.00	31,781.13	6,537.05	7,802.88	2,414.50	737	2.50	3,075.00
Buchanan.....	108,502.42	40,551.93	47,511.06	8,310.67	8,778.24	2,133.00	615	2.50	2,195.00
Buena Vista.....	120,053.25	50,285.59	47,470.75	8,310.67	7,802.88	2,149.50	439	2.50	2,030.00
Butler.....	111,345.74	43,749.23	55,449.13	8,360.31	8,290.56	2,062.00	406	2.50	1,925.00
Calhoun.....	88,557.18	32,796.40	35,017.91	8,360.31	7,802.88	1,894.00	385	2.50	905.00
Carroll.....	117,352.77	40,004.52	58,681.37	9,140.62	8,290.56	2,454.00	2	2.50	2,350.00
Cass.....	113,301.85	46,759.77	54,360.20	9,140.62	7,802.88	2,313.50	181	2.50	1,500.00
Cedar.....	110,587.80	37,238.09	52,700.03	6,780.69	7,802.88	5,540.50	2	2.50	1,835.00
Carro Gordo.....	108,192.80	49,149.81	40,918.42	6,070.17	7,802.88	1,736.00	470	2.50	3,120.00
Cherokee.....	116,341.42	56,175.48	42,206.89	5,651.35	5,832.16	1,882.00	300	2.50	1,175.00
Chickasaw.....	75,386.99	33,042.25	28,538.60	4,035.06	5,832.16	1,423.00	367	2.50	2,640.00
Clarke.....	55,899.76	37,761.94	19,337.00	6,890.90	7,802.88	1,465.50	624	2.50	1,880.00
Clay.....	92,927.48	39,528.39	35,404.81	8,443.30	10,728.96	3,238.50	235	2.50	2,840.00
Clayton.....	116,881.56	51,176.51	40,174.39	33,096.43	9,753.60	2,343.00	568	2.50	1,660.00
Clinton.....	145,221.03	51,132.90	46,293.10	11,449.13	10,241.28	2,997.00	332	2.50	850.00
Crawford.....	158,930.43	62,202.22	69,828.80	8,259.63	7,802.88	1,716.50	170	2.50	2,405.00
Dallas.....	109,590.51	51,468.76	37,342.24	15,414.89	7,315.20	1,784.89	481	2.50	1,285.00
Davis.....	60,246.93	20,020.16	29,845.07	15,414.89	7,315.20	2,095.50	253	2.50	2,015.00
Decatur.....	77,397.17	24,010.13	25,979.38	14,293.03	7,802.88	2,711.50	403	2.50	1,295.00
Delaware.....	105,873.15	42,248.16	38,168.58	14,293.03	6,827.52	1,977.00	2	2.50	4,080.00
Des Moines.....	68,553.27	14,756.50	32,042.75	3,859.55	5,852.16	7,052.00	2	2.50	3,260.00
Dickinson.....	53,839.90	23,862.27	19,188.92	6,877.83	8,778.24	1,002.00	259	2.50	2,50
Dubuque.....	122,577.14	39,904.32	59,059.75	4,274.52	5,852.16	3,468.50	816	2.50	2,50
Emmet.....	55,876.83	27,759.29	27,759.29	9,118.04	6,753.60	2,494.50	652	2.50	2,50
Fayette.....	148,823.93	55,906.93	66,496.26	9,118.04	6,339.84	2,494.50	2	2.50	2,50
Floyd.....	101,609.11	41,138.44	48,321.33	48,321.33	6,339.84	2,494.50	2	2.50	2,50

Franklin.....	82,748.60	32,582.11	30,473.28	7,908.33	7,802.88	1,687.00	2.50
Fremont.....	101,764.47	46,224.37	32,578.66	13,207.10	6,339.84	1,914.00	2.50
Greene.....	99,606.70	35,085.32	46,257.94	7,604.06	7,802.88	1,926.50	2.50
Grundy.....	98,933.31	38,347.79	50,568.00	.....	6,827.52	2,168.00	2.50
Guthrie.....	100,730.30	33,023.22	48,082.85	7,154.67	8,290.56	2,119.00	2.50
Hamilton.....	133,781.39	37,947.71	76,326.53	7,557.77	7,802.88	2,336.50	2.50
Hancock.....	70,250.71	27,588.96	26,494.70	5,843.17	7,802.88	1,626.00	2.50
Hardin.....	51,834.62	38,010.07	38,010.07	8,128.78	8,290.56	2,578.00	2.50
Harrison.....	49,173.17	54,904.21	54,904.21	8,097.96	7,753.60	2,801.50	2.50
Howard.....	66,180.55	14,540.03	30,180.58	11,784.78	5,852.16	2,248.00	2.50
Howard.....	74,587.46	28,640.10	31,841.54	4,857.66	5,852.16	1,526.00	2.50
Humboldt.....	80,356.08	34,165.68	30,055.28	6,168.35	6,827.52	1,329.00	2.50
Ida.....	74,815.97	30,083.58	30,332.93	6,200.80	5,852.16	1,321.50	2.50
Iowa.....	126,140.08	49,139.70	37,062.31	23,468.33	8,778.24	2,231.50	2.50
Jackson.....	107,689.69	41,696.77	46,960.05	6,808.13	8,778.24	2,356.50	2.50
Jasper.....	153,185.43	62,335.81	46,508.72	31,422.98	9,265.92	3,632.00	2.50
Jefferson.....	76,220.78	34,123.88	25,875.23	5,649.01	5,832.16	2,160.50	2.50
Johnson.....	126,171.16	58,894.00	40,538.95	8,905.43	10,241.28	2,936.50	2.50
Jones.....	105,861.68	38,552.35	40,428.61	14,674.16	8,290.56	2,746.00	2.50
Keokuk.....	117,722.01	43,798.73	53,641.04	8,160.68	8,290.56	2,746.00	2.50
Kossuth.....	167,024.80	69,259.10	48,485.83	30,611.33	13,655.04	2,623.50	2.50
Lee.....	108,576.00	41,546.78	41,427.65	14,178.01	8,290.56	3,133.00	2.50
Linn.....	140,336.92	40,743.23	62,916.84	18,866.75	9,753.60	8,056.50	2.50
Louis.....	75,113.01	22,386.27	36,192.33	5,232.25	5,852.16	1,598.50	2.50
Lucas.....	59,394.57	19,489.28	21,228.64	11,225.99	5,852.16	1,598.50	2.50
Lyon.....	74,947.80	26,245.65	28,087.36	8,748.55	8,778.24	1,513.00	2.50
Madison.....	101,272.38	33,224.84	35,109.14	20,502.02	7,802.88	1,958.50	2.50
Mahaska.....	132,010.61	52,989.60	63,537.59	.....	9,265.92	3,687.50	2.50
Marion.....	109,195.02	44,096.00	45,672.36	6,097.96	7,315.20	3,023.50	2.50
Marshall.....	137,785.38	45,306.02	46,395.92	33,055.20	8,778.24	3,390.00	2.50
Mills.....	71,082.37	32,751.78	33,439.96	5,935.29	6,339.84	1,705.50	2.50
Mitchell.....	87,612.50	37,187.01	33,082.09	5,370.31	7,802.88	1,871.50	2.50
Monona.....	103,612.50	41,720.02	41,426.56	7,308.00	9,265.92	2,012.00	2.50
Monroe.....	59,524.71	16,797.60	25,805.17	7,680.28	5,852.16	3,330.50	2.50
Monterey.....	83,201.11	37,070.16	24,464.26	17,482.03	5,852.16	2,047.50	2.50
Muscataine.....	81,119.83	49,518.99	31,092.89	8,376.61	5,852.16	2,047.50	2.50
Muscataine.....	98,930.10	49,518.99	29,003.44	4,547.82	7,315.20	2,201.50	2.50
O'Brien.....	68,815.41	27,314.48	29,084.45	14,965.20	8,290.56	2,005.50	2.50
Osceola.....	117,835.30	47,797.06	42,655.16	5,710.39	5,852.16	1,076.50	2.50
Palo Alto.....	80,921.02	26,898.37	38,249.38	5,710.39	7,802.88	2,890.00	2.50
Plymouth.....	140,893.27	54,975.31	30,682.63	36,478.01	7,802.88	2,890.00	2.50
Pocahontas.....	115,238.28	54,975.31	30,682.63	36,478.01	11,704.32	2,283.00	2.50
Polk.....	134,702.15	35,693.27	74,187.17	7,341.26	9,265.92	1,706.00	2.50
Pottawatomie.....	184,807.72	67,546.58	82,737.61	12,302.48	10,728.96	13,417.75	2.50
Poweshiek.....	129,055.69	52,504.68	57,716.74	8,574.89	13,655.04	4,006.00	2.50
Ringgold.....	74,194.80	27,882.51	36,946.41	.....	7,802.88	1,563.00	2.50
Sac.....	122,583.76	44,442.67	57,004.63	8,544.08	7,802.88	1,879.50	2.50
Scott.....	89,233.71	42,398.61	25,244.75	6,944.97	7,802.88	4,722.50	2.50
Shelby.....	122,659.52	48,553.24	63,066.90	.....	7,802.88	1,941.50	2.50
Sioux.....	102,415.29	27,194.56	46,118.64	12,036.45	11,216.64	2,849.00	2.50
Story.....	116,091.67	37,913.54	57,107.10	7,915.15	7,802.88	3,033.00	2.50

¹ The amounts shown in this column are the computed levies, based on number of men on eligible poll tax.

IOWA—Continued.

TABLE 36.—Revenue applied to roads and bridges, 1914—Continued.

County.	Total revenue applied to roads and bridges.	General county and township tax.		Other revenues applied to roads.			Statute labor revenue.			
		Bridge revenue.	Road revenue.	Source.			Number of men who worked out labor tax.	Average number of days worked.	Daily wage.	Cash value statute labor.
				Township drag tax.	Motor tax.	Poll tax. ¹				
Tama.....	\$153,174.42	\$62,013.59	\$74,700.55	.....	\$10,241.28	744	2	\$2.50	\$3,720.00	
Taylor.....	96,284.30	35,630.14	42,668.35	\$6,167.75	8,290.56	278	2	2.50	1,390.00	
Union.....	71,554.95	24,560.48	30,744.34	4,869.61	6,827.52	563	2	2.50	2,815.00	
Van Buren.....	63,515.97	22,337.20	22,533.83	8,321.92	6,827.52	301	2	2.50	1,505.00	
Wapello.....	76,456.26	30,456.38	28,258.84	5,110.52	6,827.52	256	2	2.50	1,280.00	
Warren.....	91,953.81	28,990.19	37,464.99	14,088.07	8,290.56	465	2	2.50	2,325.00	
Washington.....	116,190.39	42,046.43	52,893.33	8,875.43	7,315.20	508	2	2.50	2,540.00	
Wayne.....	61,628.34	12,809.81	31,621.41	5,146.24	7,802.88	434	2	2.50	2,170.00	
Webster.....	139,659.77	37,491.60	71,167.69	9,637.16	11,704.32	1,107	2	2.50	5,535.00	
Winnebago.....	51,340.19	9,881.00	20,102.56	12,061.47	5,852.16	399	2	2.50	1,995.00	
Winneshek.....	115,345.32	50,227.50	44,874.67	7,848.05	9,753.60	.....	2	2.50	.....	
Woodbury.....	179,800.70	72,417.03	77,340.18	9,415.17	11,704.32	509	2	2.50	2,545.00	
Worth.....	49,502.59	17,590.41	17,516.13	4,323.71	6,339.84	517	2	2.50	2,585.00	
Wright.....	119,880.67	51,853.38	48,926.90	7,767.15	8,778.24	511	2	2.50	2,555.00	
Total.....	10,113,507.32 274,000.00	3,843,294.94	4,128,493.90	896,248.60	801,258.24	.....	.....	.....	188,390.00	
Grand total.....	10,187,507.32				255,821.64					

¹ The amounts shown in this column are the computed levies, based on number of men on eligible poll tax.² State fund applied to educational and supervisory work by the State Highway Department.

KANSAS.

TABLE 37.—Revenue applied to roads and bridges, 1914.

County.	Total county and township revenue applied to roads and bridges.	Combined county and township road and bridge tax.		Other revenue applied to roads and bridges.	
		Average rate, cents per \$100.	Amount.	Source.	
				Auto fees.	Poll tax.
Allen.....	\$73,178	24	\$64,346	\$1,587	\$7,245
Anderson.....	46,668	15	38,057	640	7,971
Atchison.....	93,552	19	83,751	2,116	7,685
Barber.....	50,215	22	45,239	1,316	3,660
Barton.....	44,796	9	36,231	2,915	5,650
Bourbon.....	76,666	22	68,230	1,166	7,270
Brown.....	119,813	26	108,876	3,217	7,720
Butler.....	90,694	13	78,486	2,373	9,835
Chase.....	51,073	23.9	46,553	1,085	3,435
Chautauqua.....	49,343	29	43,775	968	4,600
Cherokee.....	70,361	22	60,185	1,316	8,860
Cheyenne.....	10,600	13	8,674	366	1,560
Clark.....	13,922	9	11,366	491	2,065
Clay.....	75,688	21.8	66,813	2,280	6,595
Cloud.....	95,655	23.9	85,333	3,532	6,790
Coffey.....	76,193	28	68,361	1,147	6,685
Comanche.....	18,059	14	15,373	651	2,035
Cowley.....	109,864	19	98,135	2,699	9,030
Crawford.....	104,564	20	88,461	2,423	13,680
Decatur.....	19,485	15	15,723	412	3,350
Dickinson.....	85,651	17	74,393	3,393	7,865
Doniphan.....	64,464	22	55,993	1,596	6,875
Douglas.....	51,602	12.3	44,939	1,298	5,365
Edwards.....	22,357	12	17,776	1,466	3,115
Elk.....	36,391	21	30,886	515	4,990
Ellis.....	44,715	21.9	40,881	679	3,155
Ellsworth.....	40,497	14	35,639	1,808	3,050
Finney.....	12,136	8	9,419	642	2,075
Ford.....	43,532	16.8	37,257	1,500	4,775
Franklin.....	83,741	22.2	74,517	1,839	7,385
Geary.....	44,226	24.4	41,739	1,282	1,205
Gove.....	5,421	4	3,269	177	1,975
Graham.....	29,253	25	25,686	402	3,165
Grant.....	1,006	2	441	50	515
Gray.....	10,878	10.6	9,295	293	1,290
Greeley.....	785	.6	202	73	510
Greenwood.....	76,517	9.6	68,467	1,260	6,790
Hamilton.....	6,909	19	5,819	185	905
Harper.....	40,722	11.7	33,973	1,774	4,975
Harvey.....	61,930	15	54,949	2,086	4,895
Haskell.....	4,062	9.7	3,419	93	550
Hodgeman.....	13,855	16	11,990	255	1,610
Jackson.....	75,082	22.2	66,154	1,453	7,475
Jefferson.....	100,603	29	91,450	1,363	7,790
Jewell.....	120,796	28	108,400	3,034	9,362
Johnson.....	110,556	15.1	101,317	1,584	7,655
Kearney.....	9,672	14.9	8,282	155	1,235
Kingman.....	53,318	15.4	46,136	1,742	5,440
Kiowa.....	24,840	13.6	21,674	896	2,270
Labette.....	70,115	11.4	60,683	1,807	7,625
Lane.....	2,767	2.1	1,305	242	1,220
Leavenworth.....	93,558	2	84,387	1,701	7,470
Lincoln.....	44,547	17.2	37,887	2,025	4,635
Linn.....	64,425	28.4	57,028	837	6,560
Logan.....	14,918	17	12,898	220	1,800
Lyon.....	97,503	21	87,129	1,924	8,450
McPherson.....	62,036	11	50,771	3,435	7,830
Marion.....	63,195	13.2	52,965	2,815	7,415
Marshall.....	90,408	16	78,362	2,241	9,805
Meade.....	25,914	23	23,417	552	1,945
Miami.....	83,004	23.5	73,051	1,418	8,535
Mitchell.....	64,599	18.7	55,649	2,950	6,000
Montgomery.....	98,984	14	85,498	3,336	10,150
Morris.....	55,051	22.3	48,525	1,136	5,390
Morton ¹	955			140	815
Nemaha.....	102,529	26	92,470	2,074	7,985
Neosho.....	54,705	15.4	46,325	1,980	6,400
Ness.....	10,863	7.6	7,790	443	2,630
Norton.....	31,739	16.8	26,595	724	4,420
Osage.....	100,292	27.8	90,673	1,289	8,330

¹ No report.

KANSAS—Continued.

TABLE 37.—Revenue applied to roads and bridges, 1914—Continued.

County.	Total county and township revenue applied to roads and bridges.	Combined county and township road and bridge tax.		Other revenue applied to roads and bridges.	
		Average rate, cents per \$100.	Amount.	Source.	
				Auto fees.	Poll tax.
Osborne.....	\$48,713	16.7	\$42,272	\$1,821	\$4,620
Ottawa.....	46,050	14.2	38,594	2,221	5,235
Pawnee.....	33,194	11.2	28,012	1,637	3,545
Phillips.....	70,211	29.1	62,283	1,468	6,460
Pottawatomie.....	87,846	25.7	78,646	1,650	7,550
Pratt.....	31,702	9.4	25,588	2,204	3,910
Rawlins.....	9,216	8	6,174	427	2,615
Reno.....	106,121	11.6	89,938	6,268	9,915
Republic.....	82,927	18.3	72,326	2,601	8,000
Rice.....	42,529	9.7	33,980	2,984	5,565
Riley.....	63,515	19.1	55,563	2,407	5,545
Rooks.....	51,451	23.9	45,661	1,525	4,265
Rush.....	19,497	9.2	14,895	1,052	3,550
Russell.....	51,622	18.3	45,472	1,480	4,670
Saline.....	48,882	9	39,312	3,235	6,335
Scott.....	2,103	1.8	930	233	940
Sedgwick.....	99,497	7.7	88,726	2,788	7,983
Seward.....	5,939	5.9	4,088	296	1,555
Shawnee.....	134,401	13.7	119,941	6,020	8,440
Sheridan.....	8,391	7.3	6,024	212	2,155
Sherman.....	15,488	15.6	13,751	422	1,315
Smith.....	71,023	22.2	60,781	2,587	7,655
Stafford.....	39,432	12.9	32,873	2,374	4,185
Stanton.....	2,891	14	2,231	70	590
Stevens.....	1,729	.9	328	131	1,270
Sumner.....	64,945	9.4	51,180	3,525	10,240
Thomas.....	9,450	6.9	7,633	337	1,480
Trego.....	11,082	9.5	8,582	385	2,115
Wabaunsee.....	79,532	30.9	73,953	259	5,320
Wallace.....	1,742	12	590	152	1,000
Washington.....	87,524	19.5	79,095	2,389	6,040
Wichita.....	1,789	2.9	969	120	700
Wilson.....	53,510	13.7	45,422	1,358	6,730
Woodson.....	48,225	29.7	43,474	641	4,110
Wyandotte.....	204,786	40.2	198,030	3,741	3,015
Total.....	5,534,968 19,080	.....	4,847,055	159,902	528,011
Grand total.....	5,544,048				

¹ Educational and advisory work carried on by State agricultural college.

MICHIGAN.

TABLE 38.—*Revenue applied to roads and bridges, 1914.*

County.	Receipts from gen- eral county and town- ship tax.	County.	Receipts from gen- eral county and town- ship tax.
Alcona.....	\$21,156.53	Lenawee.....	\$117,367.84
Alger.....	41,253.15	Livingston.....	67,605.70
Allegan.....	145,873.10	Luce.....	20,633.08
Alpena.....	74,770.62	Mackinac.....	28,371.67
Antrim.....	43,556.14	Macomb.....	126,874.70
Arenac.....	28,385.78	Manistee.....	62,629.66
Baraga.....	51,595.62	Marquette.....	177,409.84
Barry.....	59,891.71	Mason.....	59,707.66
Bay.....	211,354.62	Mecosta.....	59,189.61
Benzie.....	28,759.66	Menominee.....	88,395.05
Berrien.....	188,769.30	Midland.....	40,130.95
Branch.....	62,751.58	Missaukee.....	39,033.12
Calhoun.....	65,086.38	Monroe.....	101,411.34
Cass.....	72,348.18	Montcalm.....	79,803.54
Charlevoix.....	58,294.88	Montmorency.....	16,289.86
Cheboygan.....	63,308.25	Muskegon.....	97,597.77
Chippewa.....	70,733.72	Newaygo.....	65,174.14
Clare.....	35,555.76	Oakland.....	242,797.18
Clinton.....	96,026.84	Oceana.....	50,552.06
Crawford.....	17,963.24	Ogemaw.....	23,893.42
Delta.....	58,329.52	Ontonagon.....	122,534.06
Dickinson.....	58,107.81	Osceola.....	49,625.42
Eaton.....	99,884.62	Oscoda.....	7,577.00
Emmet.....	56,641.32	Otsego.....	18,933.54
Genesee.....	233,447.49	Ottawa.....	125,584.37
Gladwin.....	39,525.30	Presque Isle.....	25,259.71
Gogebic.....	199,460.60	Roscommon.....	12,776.48
Grand Traverse.....	57,567.57	Saginaw.....	249,934.09
Gratiot.....	92,716.40	Sanilac.....	109,414.72
Hillsdale.....	102,780.59	Schoolcraft.....	28,112.11
Houghton.....	158,945.17	Shiawassee.....	123,750.62
Huron.....	117,431.91	St. Clair.....	157,613.73
Ingham.....	146,742.42	St. Joseph.....	66,812.01
Ionia.....	75,261.30	Tuscola.....	128,362.27
Iosco.....	34,439.64	Van Buren.....	81,809.05
Isabella.....	66,526.79	Washtenaw.....	75,203.26
Iron.....	135,902.12	Wayne.....	169,627.51
Jackson.....	201,133.66	Wexford.....	49,580.09
Kalamazoo.....	117,254.80		
Kalkaska.....	34,075.66	Total.....	7,080,177.00
Keweenaw.....	37,875.61		¹ 657,264.00
Kent.....	236,150.97		² 1,524,557.00
Lake.....	20,028.73		
Lapeer.....	69,052.93	Grand total.....	9,261,998.00
Leelanau.....	26,080.78		

¹ State reward fund.² Estimated expenditures from local bond funds.

MINNESOTA.

TABLE 39.—Revenue applied to roads and bridges, 1914.

County.	Total revenue applied to roads and bridges.	General county and township tax.		Other revenue applied to roads.			State tax for roads and bridges (1 mill).
		Rate, mills per \$1.	Receipts.	State aid to counties.	Miscellaneous revenue.		
					Amount.	Source.	
Aitkin.....	\$70,717.42	13.35	\$54,217.42	\$16,500			\$5,316.05
Anoka.....	55,072.56	6.58	39,572.56	15,500			4,987.83
Becker.....	36,548.16	4.67	22,548.16	14,000			7,371.28
Beltrami.....	66,430.13	10.51	49,430.13	17,000			6,823.39
Benton.....	39,321.02	8.09	23,821.02	15,500			4,133.21
Big Stone.....	32,075.95	4.30	16,575.95	15,500			5,537.89
Blue Earth.....	58,213.40	2.09	39,213.40	19,000			15,678.14
Brown.....	55,724.59	5.48	41,724.59	14,000			9,980.20
Carlton.....	49,129.89	7.48	32,629.89	16,500			5,481.86
Carver.....	55,056.88	4.05	39,256.88	14,000	\$1,800	City and town donations.	7,783.52
Cass.....	64,403.53	10.11	49,403.53	15,000			5,347.29
Chippewa.....	54,115.70	3.33	40,115.70	14,000			7,571.18
Chisago.....	39,116.59	5.15	24,616.59	14,500			4,976.96
Clay.....	49,692.87	4.95	35,692.87	14,000			9,769.92
Clearwater.....	29,230.45	7.28	15,230.45	14,000			2,155.33
Cook.....	39,871.70	10.28	24,371.70	15,500			2,052.32
Cottonwood.....	59,553.78	3.88	45,553.78	14,000			8,454.37
Crow Wing.....	50,499.55	4.85	35,999.55	14,500			7,604.09
Dakota.....	69,082.72	3.76	50,082.72	19,000			12,111.98
Dodge.....	37,629.56	5.72	23,629.56	14,000			7,001.36
Douglas.....	40,971.86	3.95	26,971.86	14,000			6,833.48
Faribault.....	62,272.42	3.54	46,772.42	15,500			12,826.78
Fillmore.....	74,959.41	4.68	58,959.41	16,000			12,842.16
Freeborn.....	84,304.91	4.92	68,804.91	15,500			11,898.92
Goodhue.....	107,455.11	5.21	89,955.11	17,500			15,048.36
Grant.....	31,417.37	4.57	17,417.37	14,000			5,352.10
Hennepin.....	76,277.91	2.15	41,277.91	35,000			236,476.64
Houston.....	50,872.56	6.34	35,872.56	15,000			6,125.59
Hubbard.....	42,605.32	8.74	28,605.32	14,000			3,500.70
Isanti.....	41,715.87	8.83	27,215.87	14,500			3,475.32
Itasca.....	232,014.12	6.63	152,797.47	28,000	51,216.65	Transfer of funds	25,714.50
Jackson.....	83,078.08	5.38	62,463.08	15,000	5,000.00	Town appropriation.	10,222.74
Kanabec.....	32,340.95	9.85	18,340.95	14,000	615.00	Liquor licenses.	2,426.75
Kandiyohi.....	74,612.38	5.42	58,612.38	16,000			9,473.48
Kittson.....	49,953.88	6.21	35,953.88	14,000			5,983.22
Koochiching.....	69,018.36	10.79	50,018.36	19,000			6,924.03
Lac qui Parle.....	78,751.60	2.98	53,720.33	14,500	10,531.27	Township drag tax.	9,688.45
Lake.....	58,250.47	11.11	44,250.47	14,000			4,268.75
Le Sueur.....	48,089.56	3.54	32,089.56	16,000			8,280.06
Lincoln.....	52,665.99	5.23	38,665.99	14,000			6,174.40
Lyon.....	76,775.01	5.35	62,775.01	14,000			10,205.73
McLeod.....	71,352.44	3.86	57,352.44	14,000			9,368.26
Mahnomen.....	26,725.39	9.05	12,725.39	14,000			2,110.41
Marshall.....	55,342.82	7.06	40,342.82	15,000			8,097.96
Martin.....	75,756.71	5.89	60,756.71	15,000			11,453.49
Meeker.....	78,289.29	5.83	62,289.29	16,000			8,415.17
Mille Lacs.....	56,791.83	9.05	28,791.83	28,000			3,336.12
Morrison.....	56,063.88	5.72	41,563.88	14,500			7,552.45
Mower.....	79,188.55	4.37	64,188.55	15,000			12,622.87
Murray.....	49,284.75	3.97	35,284.75	14,000			9,154.15
Nicollet.....	58,240.84	4.09	19,217.84	16,000	23,023.00	City, village, and township levy.	7,033.26
Nobles.....	42,750.85	3.32	28,750.85	14,000			11,324.61
Norman.....	40,785.93	5.41	26,785.93	14,000			6,737.56
Olmsted.....	75,639.96	5.15	57,939.96	16,000	1,700.00	Liquor licenses.	11,476.69
Otter Tail.....	97,298.36	5.99	79,798.36	17,500			14,047.00
Pennington.....	27,293.69	5.73	13,293.69	14,000			3,441.29
Pine.....	65,647.91	10.42	50,522.91	14,500	625.00	Liquor licenses.	5,705.30
Pipestone.....	32,208.51	3.17	18,208.51	14,000			6,633.95
Polk.....	80,354.76	6.70	63,354.76	17,000			14,496.90
Pope.....	31,452.57	4.88	17,452.57	14,000			6,200.46
Ramsey.....	156,072.34	.88	121,072.34	35,000			142,934.29
Red Lake.....	29,038.39	7.43	15,038.39	14,000			2,371.59
Redwood.....	47,748.88	3.53	33,248.88	14,500			11,737.08
Renville.....	68,912.29	4.48	52,912.29	16,000			13,232.10
Rice.....	74,076.41	3.69	58,576.41	15,500			11,330.43

MINNESOTA—Continued.

TABLE 39.—Revenue applied to roads and bridges—Continued.

County.	Total revenue applied to roads and bridges.	General county and township tax.		Other revenue applied to roads.			State tax for roads and bridges (1 mill)
		Rate, mills per \$1.	Receipts.	State aid to counties.	Miscellaneous revenue.		
					Amount.	Source.	
Rock	\$53,735.85	4.65	\$39,735.85	\$14,000			\$8,581.52
Roseau	42,020.80	9.63	28,020.80	14,000			4,281.98
St. Louis	923,177.63	2.91	888,177.63	35,000			314,817.26
Scott	33,977.96	5.15	15,877.96	16,000	\$2,100.00	City and town donations.	6,211.27
Sherburne	37,266.47	6.18	20,766.47	16,500			3,083.47
Sibley	66,789.23	4.44	52,789.23	14,000			8,780.60
Stearns	74,017.43	5.55	53,017.43	21,000			18,144.91
Steele	41,983.31	3.67	26,483.31	15,500			7,821.56
Stevens	45,032.45	5.45	29,532.45	15,500			5,651.60
Swift	45,667.89	4.13	30,167.89	15,500			7,707.94
Todd	58,169.12	5.13	44,169.12	14,000			7,373.50
Traverse	33,294.19	3.75	19,294.19	14,000			5,947.30
Wabasha	41,405.31	4.22	25,905.31	15,500			8,292.84
Wadena	30,994.65	6.44	16,994.65	14,000			2,799.74
Waseca	43,458.43	5.03	29,458.43	14,000			6,883.49
Washington	47,273.46	4.23	30,773.46	16,500			10,363.85
Watonwan	42,052.53	4.03	28,052.53	14,000			6,886.05
Wilkin	29,323.41	6.63	14,833.41	14,000	490.00	Liquor licenses..	6,575.30
Winona	79,181.23	2.97	49,181.23	30,000			15,052.78
Wright	95,133.76	5.72	79,133.76	16,000			10,487.68
Yellow Medicine	65,193.02	3.96	51,193.02	14,000			9,481.59
Total	5,885,355.07 1 143,785.00 2 429,800.00		4,388,254.15	1,400,000	97,100.92		1,369,969.95
Grand total	6,458,940.07						

¹ Maintenance State highway department, 1914.² Local bond expenditure.

MISSOURI.

TABLE 40.—Revenue applied to roads and bridges, 1914.

County.	Total revenue applied to roads and bridges.	General county fund, roads and bridges.		Other revenue applied to roads and bridges.						Statute labor tax.			
		Rate, cents per \$100.	Amount.	From shops.	From option stamps.	From auto revenue.	From general State fund.	From special funds.		Num-ber of men who worked.	Num-ber of days labor.	Daily wage.	Cash value of statute labor.
								Amount.	Source.				
Adair.....	\$60, 110. 70	40	\$32, 271. 47	.....	\$183. 01	\$956. 22	\$1, 200. 00	\$18, 000. 00	Special tax.....	2, 500	2	\$1. 50	\$7, 500. 00
Andrew.....	106, 740. 77	50	68, 942. 64	.....	125. 00	540. 00	1, 839. 13	36, 294. 00	do.....	1, 500	1	2. 00	3, 000. 00
Atchison.....	62, 690. 79	25	44, 347. 53	.....	110. 55	736. 56	2, 096. 15	{ 5, 400. 00	Pol tax.....	.....	.....	.....	.....
.....	.....	.....	.....	.....	.....	.....	.....	{ 10, 000. 00	General fund.....	.....	.....	.....	.....
Audrain.....	47, 626. 87	35	43, 292. 78	.....	172. 15	1, 185. 64	2, 176. 30	{ 1, 000. 00	Donations.....	.....	.....	.....	.....
Barry.....	33, 256. 49	25	27, 467. 87	.....	224. 35	810. 00	1, 754. 27	{ 6, 000. 00	Pol tax.....	2, 000	2	3. 00	12, 000. 00
.....	.....	.....	.....	.....	.....	.....	.....	{ 2, 000. 00	Donations.....	2, 500	2	1. 25	6, 250. 00
Barton.....	24, 771. 49	25	2, 719. 44	.....	150. 45	618. 72	2, 282. 88	{ 1, 503. 36	Revenue and interest.....	.....	.....	.....	.....
.....	.....	.....	.....	.....	.....	.....	.....	{ 1, 322. 32	Special tax.....	.....	.....	.....	.....
Bates.....	58, 379. 61	.....	13, 752. 87	.....	203. 74	757. 50	3, 015. 50	{ 3, 798. 62	Donations.....	2, 710	2	1. 50	8, 130. 00
.....													
Benton.....	45, 345. 66	35	27, 641. 56	.....	129. 24	841. 86	878. 70	{ 1, 200. 00	Insurance from county.....	.....	.....	.....	.....
.....	.....	.....	.....	.....	.....	.....	.....	{ 9, 634. 00	Pol tax.....	2, 007	3	1. 50	9, 031. 50
Bollinger.....	14, 264. 87	35	12, 976. 50	.....	136. 37	750. 00	402. 00	{ 10, 000. 00	Pol tax.....	2, 500	3	1. 50	11, 250. 00
Boone.....	69, 003. 20	35	46, 715. 08	.....	230. 15	551. 22	2, 241. 00	{ 6, 500. 00	Pol tax.....	.....	.....	.....	.....
Buchanan.....	245, 004. 36	18	178, 577. 37	.....	676. 35	500. 64	5, 250. 00	{ 966. 50	Special tax.....	16, 000	2	1. 75	56, 000. 00
Butler.....	72, 225. 85	25	37, 497. 17	.....	209. 18	795. 00	1, 127. 84	{ 468. 20	Miscellaneous.....	.....	.....	.....	.....
.....	.....	.....	.....	.....	.....	.....	.....	{ 336. 50	Donations.....	1, 688	4	1. 25	8, 440. 00
Caldwell.....	30, 816. 36	.....	11, 833. 06	.....	114. 35	645. 00	1, 723. 95	{ 2, 900. 00	Special tax.....	4, 000	2	2. 00	16, 000. 00
.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	125	4	1. 50	750. 00
Callaway.....	122, 906. 98	35	45, 854. 01	.....	178. 33	577. 50	1, 630. 64	{ 2, 900. 00	Special tax.....	.....	.....	.....	.....
.....													
Camden.....	17, 952. 98	25	16, 298. 08	.....	107. 55	960. 00	587. 35	{ 468. 20	Miscellaneous.....	.....	.....	.....	.....
.....													
Cape Girardeau.....	44, 179. 50	35	22, 025. 00	.....	253. 00	858. 72	1, 631. 42	{ 336. 50	Donations.....	1, 688	4	1. 25	8, 440. 00
Carroll.....	10, 938. 44	.....	7, 595. 01	.....	181. 78	957. 78	2, 203. 87	{ 2, 900. 00	Special tax.....	4, 000	2	2. 00	16, 000. 00
Cartier.....	2, 636. 44	25	1, 441. 65	.....	51. 35	772. 50	370. 94	{ 2, 900. 00	Special tax.....	125	4	1. 50	750. 00
Cass.....	41, 539. 95	25	21, 500. 00	.....	177. 45	840. 00	3, 022. 50	{ 2, 900. 00	Special tax.....	.....	.....	.....	.....
Cedar.....	36, 610. 13	25	31, 394. 55	.....	132. 05	622. 50	811. 03	{ 2, 900. 00	Special tax.....	.....	.....	.....	.....
.....													
Christian.....	16, 788. 35	37	13, 536. 35	.....	202. 45	967. 50	2, 082. 04	{ 2, 900. 00	Special tax.....	.....	.....	.....	.....
.....													
Clark.....	42, 888. 09	35	40, 842. 91	.....	146. 83	776. 22	1, 947. 11	{ 2, 900. 00	Special tax.....	.....	.....	.....	.....
.....													
Clay.....	32, 431. 37	40	2, 666. 66	.....	152. 48	510. 00	1, 130. 87	{ 2, 900. 00	Special tax.....	.....	.....	.....	.....
.....													
Clinton.....	32, 460. 32	35	30, 000. 00	.....	119. 22	641. 22	1, 693. 88	{ 2, 900. 00	Special tax.....	.....	.....	.....	.....

Cole.....	55,367.37	25	39,117.87	166.15	353.22	1,109.47	.....	.....	1,212	3	1.50	5,454.00
Cooper.....	88,266.81	40	80,034.63	157.35	750.00	1,958.17	.....	.....	.....	.....	.....	.....
Crawford.....	16,202.35	30	6,751.62	122.95	1,032.50	718.53	.....	.....	1,099	4	1.20	5,275.20
Dade.....	30,318.76	5	10,510.59	136.76	708.84	882.57	.....	.....	.....	.....	.....	.....
Dallas.....	17,153.25	25	3,455.40	128.56	806.22	812.27	.....	.....	2,400	3½	1.20	10,080.00
Davess.....	37,832.48	25	14,981.29	144.50	825.00	1,881.68	.....	.....	1,631	4	1.20	7,828.80
Dekalb.....	40,706.14	45	22,457.01	98.95	600.00	1,550.18	.....	.....	2,000	2	1.75	7,000.00
Denton.....	15,095.13	25	12,409.13	131.00	1,755.00	800.00	.....	.....	2,000	2	2.00	8,000.00
Doutels.....	9,132.56	25	6,533.74	169.67	1,125.00	683.09	.....	.....	.....	.....	.....	.....
Dunklin.....	21,776.49	35	19,211.65	305.46	851.22	1,308.16	.....	.....	.....	.....	.....	.....
Franklin.....	224,939.35	35	68,573.86	261.41	417.50	1,945.40	.....	.....	16,554	3	2.00	99,324.00
Gastonade.....	22,749.55	35	29,703.22	122.77	892.50	942.74	.....	.....	.....	.....	.....	.....
Gentry.....	36,245.06	38	9,507.76	136.65	772.50	1,138.63	.....	.....	.....	.....	.....	.....
Greene.....	146,950.00	20	16,046.13	485.00	900.00	4,612.28	.....	.....	.....	.....	.....	.....
Grundy.....	11,861.94	23	7,914.12	131.05	750.00	933.45	.....	.....	.....	.....	.....	.....
Harrison.....	30,000.00	25	13,287.37	178.10	958.38	1,856.17	.....	.....	.....	.....	.....	.....
Henry.....	44,269.86	25	17,852.22	214.51	970.20	1,832.93	.....	.....	1,000	4	1.50	6,000.00
Hickory.....	13,500.79	25	9,239.64	379.80	487.50	1,528.85	.....	.....	1,146	2	1.25	2,865.00
Holt.....	53,079.66	35	44,263.72	123.85	687.44	1,694.05	.....	.....	400	1½	2.00	1,200.00
Howard.....	49,959.44	35	46,892.66	119.28	622.50	1,125.00	.....	.....	.....	.....	.....	.....
Howell.....	30,467.32	20	11,796.43	208.42	945.00	983.67	.....	.....	.....	.....	.....	.....
Iron.....	6,853.39	25	3,544.08	87.11	796.20	1,000.00	.....	.....	1,971	4	1.95	15,373.80
Jackson.....	224,812.22	21	58,549.31	2,452.02	1,169.37	5,250.00	.....	.....	.....	.....	.....	.....
Jasper.....	167,692.37	25	132,886.92	28,206.66	705.00	5,098.25	.....	.....	.....	.....	.....	.....
Jefferson.....	82,828.40	35	58,218.01	14,000.00	240.00	1,654.59	.....	.....	.....	.....	.....	.....
Johnson.....	33,449.92	25	30,000.00	204.79	753.72	2,491.41	.....	.....	1,256	2½	1.50	4,710.00
Knox.....	30,654.06	30	26,227.57	97.07	701.22	1,198.20	.....	.....	500	1	3.00	1,500.00
Laclede.....	22,333.13	25	11,288.78	163.55	798.00	482.80	.....	.....	2,000	4	1.20	9,600.00
Lafayette.....	70,484.78	20	45,680.53	258.57	802.50	2,563.18	.....	.....	.....	.....	.....	.....
Lawrence.....	29,636.63	25	27,116.89	225.40	900.00	1,394.34	.....	.....	.....	.....	.....	.....
Lewis.....	32,011.71	35	15,425.68	119.11	877.50	1,218.04	.....	.....	1,250	3	1.50	5,625.00
Lincoln.....	57,281.33	35	49,007.35	134.42	795.00	1,319.56	.....	.....	.....	.....	.....	.....
Linn.....	25,752.70	25	21,512.93	936.06	1,902.46	2,876.99	.....	.....	.....	.....	.....	.....
Livingston.....	17,110.66	25	13,161.78	171.89	708.72	550.00	.....	.....	.....	.....	.....	.....
McDonald.....	25,906.97	25	20,426.40	139.16	708.72	550.00	.....	.....	.....	.....	.....	.....
Macon.....	28,244.37	25	25,000.00	235.65	1,008.72	2,000.00	.....	.....	1,283	3	1.50	5,775.50
Madison.....	13,782.87	20	5,356.66	102.43	450.00	2,100.28	.....	.....	850	2	2.40	4,080.00
Maries.....	16,679.28	30	9,282.04	93.35	592.50	505.31	.....	.....	.....	.....	.....	.....
Marion.....	82,896.60	35	64,311.30	15,333.32	750.00	2,240.51	.....	.....	.....	.....	.....	.....
Mercer.....	21,176.04	10	10,491.66	169.51	697.50	1,350.00	.....	.....	.....	.....	.....	.....
Miller.....	22,439.45	35	21,080.78	153.74	767.22	1,737.71	.....	.....	.....	.....	.....	.....
Mississippi.....	47,424.60	35	24,027.89	114.78	324.62	957.31	.....	.....	2,000	4	1.20	21,000.00
Moniteau.....	42,625.02	35	18,369.73	120.75	581.22	1,000.00	.....	.....	1,400	4	1.20	6,720.00

MISSOURI—(Continued).
TABLE 40.—Revenue applied to roads and bridges, 1914—Continued.

County.	Total revenue applied to roads and bridges.	General county fund, roads and bridges.				Other revenue applied to roads and bridges.						Statute labor tax.			
		Rate, cents per \$100.	Amount.	From dram-shops.	From option stamps.	From auto revenue.	From general State fund.	From special funds.		Num-ber of men who worked.	Num-ber of days labor.	Daily wage.	Cash value of statute labor.		
								Amount.	Source.						
Monroe.....	\$65,009.14	40	\$51,058.81		\$136.09	\$882.77	\$1,681.47			2,500	3	\$1.50	\$11,250.00		
Montgomery.....	66,879.97	25	59,634.82		117.70	757.56	1,203.89			1,722	2	1.50	5,166.00		
Morgan.....	24,283.93	35	10,590.00	\$333.32	110.24	592.50	756.87		Donations.	1,133	1½	1.50	2,266.00		
New Madrid.....	29,388.14	10	26,848.71		189.95		2,349.48		Poll tax.	3,071	3	1.20	11,055.60		
Newton.....	49,119.53	25	35,558.68		254.26	750.00	1,500.99			1,500	3½	1.25	7,031.25		
Nodaway.....	59,030.14	25	52,940.98	1,066.66	232.98	1,710.00	3,079.52			1,800	4	1.50	10,800.00		
Oregon.....	27,665.53	35	11,390.95		141.42	831.00	670.91		Poll tax.	1,500	3½	1.25	7,031.25		
Osage.....	51,885.00	40	33,253.60	6,000.00	133.33	727.50	968.57			1,800	4	1.50	10,800.00		
Ozark.....	3,662.51	10	1,757.39		640.50	772.50	492.12		Township tax.	1,183	2	1.50	3,549.00		
Pemiscot.....	30,208.64	15	13,290.00	6,933.32	167.30	561.36	1,406.50			550	2	1.50	1,650.00		
Perry.....	22,277.05	25	10,535.18	6,833.32	150.55	802.50	2,694.26			2,121	2	1.50	6,363.00		
Pettis.....	116,584.31	45	98,643.02	11,600.00	263.28	1,733.75	965.57			2,600	5	1.20	15,600.00		
Phelps.....	20,994.73	35	19,131.67		145.63	751.86	1,952.38		From petitioners.	1,200	5	1.50	7,200.00		
Pike.....	54,965.39	30	38,319.00	4,266.66	179.35	765.00	1,553.26		Poll tax.	1,200	5	1.50	7,200.00		
Platte.....	35,912.71	30	27,000.00	4,000.00	118.23	641.22	1,600.00			1,200	5	1.50	7,200.00		
Polk.....	44,973.66	35	26,820.41		188.25	765.00	556.59		Donations.	1,600	3	1.20	5,760.00		
Pulaski.....	11,652.00	25	2,445.19		111.47	1,338.75				1,600	3	1.20	5,760.00		
Putnam.....	45,560.29	25	12,946.45		118.61	810.00	1,175.23		Poll tax.	1,600	3	1.20	5,760.00		
Ralls.....	30,422.69	45	12,948.11	1,333.32	98.27	633.72	1,159.58		Special road district.						
Randolph.....	46,465.03	35	43,452.01		220.98	787.50	2,004.54		Railroad bonds.						
Ray.....	41,299.06	25	38,715.16		181.40	802.50	1,360.00		Poll tax.						
Reynolds.....	11,386.76	10	8,965.00		95.25	1,460.62	475.89		County revenues, etc.						
Ripley.....	18,186.77	25	9,520.00		128.21	562.50	675.06		Interest on daily balances	1,700	4	1.00	6,800.00		
St. Charles.....	78,196.32	15	41,363.25	16,000.00	208.13	847.50	2,578.34		Donations.						
St. Clair.....	12,877.83	35	10,400.22		134.15	1,995.23	348.23		County revenue.						
St. Genevieve.....	31,040.09	35	21,060.01	6,666.66	108.10	405.00	630.05		Interest on earnings.						
St. Francois.....	74,834.75	35	52,405.48	11,466.66	280.90	645.00	2,106.71		Railroad and telegraph tax.						
St. Louis.....	443,910.15	25	377,712.89	59,500.00	702.30	983.97	5,011.89		Road district tax.						

Saline.....	87,490.14	25	65,182.73	.....	232.80	675.00	2,751.61	18,648.00	From county revenue.	.....	.....	.....
Schuyler.....	30,068.14	35	15,676.54	.....	75.90	671.27	677.17	{ 6,768.00 2,679.00	Poll tax..... Donations.....	.....	.....	.....
Scotland.....	31,249.89	45	29,499.46	.....	91.71	678.72	980.00	3,526.26	Road district.....	.....	.....	.....
Scott.....	62,086.81	25	46,232.13	.....	192.70	469.86	1,412.12	.....	.....	.....	.....	.....
Shannon.....	20,802.11	25	13,067.00	13,780.00	119.20	1,035.00	673.91	.....	1,969	2	1.50	5,907.00
Shelby.....	22,225.96	25	19,693.48	.....	118.79	720.72	1,692.97	.....	.....	.....	.....	.....
Stoddard.....	49,805.13	25	34,824.18	.....	263.72	1,136.22	1,581.01	.....	2,000	4	1.50	12,000.00
Stone.....	7,975.72	75	3,100.28	.....	118.41	1,383.75	873.28	2,500.00	Donations.....	.....	.....	.....
Sullivan.....	10,791.61	25	7,507.95	.....	165.25	677.22	921.19	1,520.00	do.....	.....	.....	.....
Taney.....	18,736.65	25	10,056.95	.....	99.00	802.50	578.20	.....	1,200	4	1.50	7,200.00
Texas.....	10,422.92	20	7,960.49	.....	217.68	1,432.50	812.25	.....	.....	.....	.....	.....
Vernon.....	14,538.96	25	11,039.69	.....	239.42	1,074.36	2,205.49	.....	.....	.....	.....	.....
Warren.....	13,851.43	35	8,045.02	.....	78.77	581.22	813.10	.....	.....	.....	.....	.....
Washington.....	6,027.32	10	4,343.02	4,333.32	124.30	660.00	900.00	.....	.....	.....	.....	.....
Wayne.....	33,680.69	35	24,579.29	.....	142.06	1,110.00	749.34	.....	1,820	4	1.25	7,100.00
Webster.....	33,248.26	25	21,651.08	.....	172.36	791.22	883.60	{ 1,000.00 8,750.00	Donations..... Poll tax.....	.....	.....	.....
Worth.....	17,281.87	25	15,954.58	.....	71.37	442.50	813.42	.....	.....	.....	.....	.....
Wright.....	19,267.56	25	14,327.48	.....	184.68	632.72	742.68	.....	700	4	1.20	3,360.00
Total.....	5,450,482.71	.....	3,508,219.39	518,416.46	23,083.19	93,783.58	175,101.17	636,460.27	.....	.....	.....	505,418.65
	155,000.00	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
	27,566.00	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Grand total..	5,513,048.71	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....

1 Expended from bond-issue funds.

2 Administration of State highway department.

MONTANA.

TABLE 41.—Revenue for roads and bridges, 1914.

County.	Total revenue applied to roads and bridges.	General county road and bridge tax.		Other revenue applied to roads and bridges.	
		Rate, mills per \$1.	Amount.	Amount.	Source.
Beaverhead.....	\$51,188.62	5	\$39,744.10	\$11,444.52	Balance from 1913.
Big Horn.....	22,778.80	2.5	12,040.46	9,724.29	Do.
Blaine.....	28,034.61	1	9,602.25	1,014.05	From State highway fund.
Broadwater.....	31,359.33	3.5	13,330.00	18,432.36	Balance from 1913.
Carbon.....	87,830.05	5	51,350.21	36,497.84	Do.
Cascade.....	113,573.59	3	58,845.18	54,728.41	Do.
Chouteau.....	60,447.91	4	35,061.75	25,386.16	Do.
Custer.....	224,811.45	4.5	162,140.78	62,670.67	Do.
Dawson.....	72,926.35	5	54,877.30	18,049.05	Do.
Deerlodge.....	36,542.03	3	18,982.45	17,559.58	Do.
Fallon.....	29,105.83	5	29,105.83		
Fergus.....	179,744.32	5	99,388.53	79,971.79	Do.
Flathead.....	109,942.59	5	56,805.57	384.00	Lewiston special fund.
Gallatin.....	65,875.46	5	59,651.88	53,137.02	Balance from 1913.
Granite.....	27,308.82	4	13,865.97	6,223.58	Do.
Hill.....	82,223.90	5	46,390.75	13,442.85	Do.
Jefferson.....	35,362.53	2.5	24,430.77	35,833.15	Do.
Lewis and Clark.....	44,060.37	3	32,849.83	10,931.75	Do.
Lincoln.....	128,329.29	5	99,678.30	11,210.54	Do.
Madison.....	66,626.47	4	30,041.59	28,650.99	Do.
Meagher.....	59,708.46	3.5	32,509.56	7,178.11	District road fund.
Mineral.....	9,524.15	2.5	9,524.15	29,406.77	Balance from 1913.
Missoula.....	81,970.71	2.5	77,319.34	27,198.90	Do.
Musselshell.....	56,802.39	2	25,733.52	4,651.37	Do.
Park.....	61,206.64	5	60,633.46	31,068.87	Do.
Phillips ¹				573.18	
Powell.....	65,999.38	5	39,678.92	26,320.46	Do.
Prairie.....	16,009.00	3	16,009.00		
Ravalli.....	45,798.40	3	23,605.62	22,192.78	Do.
Richland.....	19,843.12	5	19,843.12		
Rosebud.....	109,968.55	5	64,328.23	45,640.32	Do.
Sanders.....	82,617.75	3	66,036.11	16,581.64	Do.
Sheridan.....	83,678.71	3	63,482.20	20,196.51	Do.
Silverbow.....	81,566.37	2	59,809.10	21,757.27	Do.
Stillwater.....	65,766.24	5	47,115.04	18,651.20	Do.
Sweet Grass.....	31,657.59	3.5	16,313.99	15,343.60	Do.
Teton.....	197,297.27	3	70,400.11	31,080.81	Do.
Toole.....	10,750.21	3	8,832.21	95,816.35	Road and bridge fund and awards.
Valley.....	78,023.42	3	42,740.00	1,868.00	Special road fund.
Wibaux.....	11,624.55	5	11,624.55	35,283.42	Balance from 1913.
Yellowstone.....	104,524.67	5	61,186.15	43,338.52	Do.
Total.....	2,772,409.90		1,764,957.88	1,007,452.02	
	² 13,515.71				
	³ 102,475.00				
Grand total..	2,888,400.61				

¹ No report.² Expenditure by State highway commission from motor-vehicle fund.³ Expenditure from county bond issues.

NEBRASKA.

TABLE 42.—Revenue applied to roads and bridges, 1914.

County.	Total revenue applied to roads and bridges.	General county and township tax.		Other revenue applied to roads and bridges.				
		Rate, mills per \$1.	Amount.	Poll tax.	Automobile fund (\$2 per car).	State aid bridge fund.	Amount.	Miscellaneous sources
Adams.....	\$22,000.87	.....	\$20,000.00	.....	\$1,064	\$1,536.87	.....	
Antelope.....	31,856.46	.....	30,198.75	.....	586	1,071.71	.....	
Arthur.....	1,498.95	3	697.19	\$755.00	.....	46.76	.....	
Banner.....	1,364.52	1	485.00	755.00	28	46.52	.....	
Blaine.....	2,302.89	2.5	1,650.00	500.00	32	120.89	.....	
Boone.....	30,141.82	.....	22,587.54	.....	566	1,130.28	\$5,858.00	Road drag fund.
Box Butte.....	4,953.12	2	4,339.23	.....	200	413.89	.....	
Boyd.....	9,245.13	3	8,449.80	.....	232	503.33	.....	
Brown.....	7,749.08	3	5,000.00	2,200.00	174	375.08	.....	
Buffalo.....	3,335.86	.....	.....	88.50	774	1,510.36	963.00	Inheritance tax.
Burt.....	25,030.82	.....	18,964.38	3,910.00	766	1,370.44	5,000.00	Do.
Butler.....	58,010.90	.....	46,282.00	4,232.00	890	1,606.90	.....	
Cass.....	27,553.03	3	125,000.00	.....	876	1,677.03	.....	
Cedar.....	18,719.57	1.1	9,000.00	6,250.00	818	1,651.57	1,000.00	Do.
Chase.....	3,549.09	3	3,176.43	.....	162	210.66	.....	
Cherry.....	21,781.67	3	14,765.00	6,083.50	174	759.17	.....	
Cheyenne.....	11,070.90	3	8,276.30	2,012.50	222	560.10	.....	
Clay.....	32,007.31	10	43,186.00	6,122.00	1,116	1,583.31	.....	
Colfax.....	19,273.88	.....	17,500.00	4,296.23	606	1,167.88	.....	
Cuming.....	30,785.36	5.1	22,698.47	10,207.91	782	1,585.66	1,589.00	Do.
Custer.....	74,549.50	8.6	61,604.97	.....	616	1,484.22	470.40	Do.
Dakota.....	40,505.49	3	9,577.50	.....	292	635.99	.....	
Dawes.....	14,432.28	6	13,864.14	.....	106	462.14	.....	
Dawson.....	25,985.47	4	24,000.00	.....	670	1,313.47	.....	
Deuel.....	2,319.42	.....	2,000.00	.....	70	249.42	.....	
Dixon.....	43,233.05	9	41,785.00	.....	518	930.05	.....	
Dodge.....	14,070.01	6.6	5,784.46	.....	1,366	1,920.15	5,000.00	Do.
Douglas.....	48,309.43	.....	23,453.69	.....	3,294	9,333.82	12,207.92	Do.
Dundy.....	3,432.44	.....	3,000.00	.....	126	306.44	.....	
Fillmore.....	9,897.36	3.2	7,634.00	.....	790	1,473.36	.....	
Franklin.....	5,078.40	1	3,817.00	.....	498	763.40	.....	
Frontier.....	9,294.96	4	5,416.64	3,183.00	154	541.32	.....	
Furnas.....	12,908.57	2	11,354.42	400.50	356	797.65	.....	
Gage.....	109,272.31	10	104,398.82	.....	1,082	2,291.49	1,500.00	Do.
Garden.....	3,294.93	4	3,000.00	.....	64	230.93	.....	

NEBRASKA—Continued.

TABLE 42.—Revenue applied to roads and bridges, 1914—Continued.

County.	Total revenue applied to roads and bridges.	General county and township tax.		Other revenue applied to roads and bridges.			
		Rate, mills per \$1.	Amount	Poll tax.	Automobile fund (\$2 per car).	State aid bridge fund.	Amount.
Garfield.....	\$3,532.53	.....	183,292.70	.....	\$98	\$151.83	.....
Gosper.....	12,331.48	5	9,868.33	\$1,921.00	158	384.15	.....
Grant.....	3,280.14	.....	2,389.77	717.05	14	159.32	.....
Greeley.....	16,224.86	9.5	15,300.00	.....	236	688.86	.....
Hall.....	6,797.94	.5	3,921.40	.....	1,040	1,563.54	\$273.00
Hamilton.....	15,757.65	.....	13,000.00	.....	1,196	1,561.65	Do.
Harlan.....	42,973.23	7.4	24,265.00	.....	380	646.23	Special township levy.
Hayes.....	4,625.70	6	4,400.00	.....	82	143.70	.....
Hitchcock.....	3,442.65	2	3,000.00	.....	102	340.65	.....
Holt.....	6,445.27	.5	2,500.00	.....	442	1,093.27	Drugging fund.
Hooker.....	1,930.09	.....	1,800.00	.....	10	130.09	Road tax.
Howard.....	15,776.51	5	13,348.12	.....	446	896.26	Inheritance and auto tax.
Jefferson.....	46,504.40	4	27,542.28	7,645.00	554	1,377.16	Drag fund.
Johnson.....	15,425.87	3.4	14,000.00	.....	490	935.87	.....
Kearney.....	4,414.29	.....	3,047.50	.....	526	840.79	.....
Keith.....	12,699.91	5	10,992.00	1,065.00	138	471.91	Inheritance tax.
Keyapaha.....	7,530.70	6	5,575.00	1,656.00	100	199.70	.....
Kimball.....	3,349.59	.....	2,405.13	.....	20	306.59	Special bridge tax.
Knox.....	49,336.95	8	48,000.00	.....	172	1,164.95	.....
Lancaster.....	31,316.18	1	24,245.00	.....	2,222	4,849.18	.....
Lincoln.....	21,573.62	.....	20,000.00	.....	476	1,097.62	.....
Logan.....	3,571.72	.....	3,379.65	.....	80	112.07	.....
Loup.....	1,897.18	2	867.77	910.00	.....	89.41	.....
Madison.....	33,219.20	.....	30,200.65	.....	756	1,387.55	Inheritance tax.
McPherson.....	551.30	.....	.....	435.08	42	74.22	.....
Merrick.....	27,936.48	6	25,673.66	.....	616	1,044.92	Do.
Morrill.....	6,380.72	3.5	6,000.00	.....	40	340.72	.....
Nemaha.....	22,460.73	1	21,067.19	.....	423	828.05	Do.
Nance.....	10,178.93	.....	8,280.00	.....	772	1,126.93	.....
Nuckolls.....	18,870.14	2	12,029.49	4,439.50	676	1,169.46	Special district levy.
Otoe.....	38,735.25	4	36,000.00	.....	998	1,737.25	.....
Pawnee.....	50,262.97	9	48,757.00	.....	426	1,079.97	.....
Perkins.....	1,355.43	.75	941.01	.....	134	280.42	.....
Phelps.....	24,655.68	5.5	23,348.00	.....	440	867.68	.....
Pierce.....	37,367.89	7	28,761.70	4,145.00	382	929.19	Special township tax.

Platte.....	48,408.67	.....	35,459.73	7,269.00	1,046	1,833.94	2,800.00	Inheritance tax.
Polk.....	12,029.42	.....	9,437.13	.....	942	1,150.29	.....	
Redwillow.....	10,132.19	3	9,275.80	.....	238	618.39	.....	
Richardson.....	31,347.86	5	26,470.07	.....	846	1,485.52	2,546.27	Do.
Rock.....	31,816.38	.....	27,484.80	.....	84	247.58	.....	
Saline.....	22,406.17	.....	20,000.00	.....	790	1,616.17	.....	
Sarpy.....	36,637.06	.....	13,617.88	.....	270	859.76	16,918.42	Appropriation for bridges and culverts.
Saunders.....	29,415.01	.....	6,175.00	.....	1,086	2,154.01	20,000.00	Special county road levy.
Scotts Bluff.....	9,527.25	.....	8,665.55	.....	284	577.70	.....	
Seward.....	6,103.59	4	3,370.39	.....	1,048	1,685.20	.....	
Sheridan.....	14,331.92	3.5	13,506.00	.....	240	585.92	.....	
Sherman.....	31,788.16	10.25	30,900.00	.....	234	654.16	.....	
Sioux.....	8,858.79	2.8	8,254.50	.....	68	317.00	219.29	Bridge fund.
Stanton.....	15,187.60	.....	14,000.00	.....	296	891.60	.....	
Thomas.....	16,936.29	.....	15,121.66	.....	596	1,218.63	.....	
Thurston.....	3,142.75	.....	3,000.00	.....	24	118.75	.....	
Valley.....	21,648.67	7	20,749.08	.....	282	617.59	.....	
Washington.....	37,051.80	.....	36,000.00	.....	330	721.80	.....	
Wayne.....	19,851.82	3	17,716.96	.....	954	1,180.86	.....	
Webster.....	18,007.14	2	11,412.20	3,170.00	532	1,140.84	1,751.10	Special road levy.
Wheeler.....	17,447.19	.....	15,714.63	.....	686	1,046.56	.....	
York.....	4,287.38	4	3,016.53	1,031.00	94	145.85	.....	
	4,745.95	.....	1,655.66	.....	1,328	1,762.29	.....	
Total.....	1,796,277.69	.....	1,454,080.65	85,399.77	47,086	94,386.83	114,724.44	

1 Includes poll tax.

NEVADA.

TABLE 43.—Revenue applied to roads and bridges, 1915.

County.	Total revenue applied to roads and bridges.	General county tax.		Poll tax.	County.	Total revenue applied to roads and bridges.	General county tax.		Poll tax.
		Rate, cents per \$100.	Amount.				Rate, cents per \$100.	Amount.	
Churchill.....	\$3,875.00	.....	\$3,075.00	\$800	Mineral.....	\$9,600.00	18	\$7,200.00	\$2,400
Clark.....	19,000.00	20	14,800.00	4,200	Nye.....	19,000.00	10	11,000.00	8,000
Douglas.....	2,750.00	38	1,250.00	1,500	Ormsby.....	5,000.00	29	4,500.00	500
Elko.....	75,000.00	21	72,600.00	2,400	Storey.....	1,000.00	.....	.....	1,000
Esmeralda.....	6,600.00	04	3,000.00	3,600	Washoe.....	30,000.00	.....	21,000.00	9,000
Eureka.....	4,800.00	07	3,600.00	1,200	White Pine.....	14,900.00	35	4,900.00	10,000
Humboldt.....	4,500.00	.....	.....	4,500	Total.....	227,756.86	.....	173,730.86	54,026
Lander.....	8,231.86	$\left\{ \begin{array}{l} 10 \\ 40 \end{array} \right\}$	7,805.86	426		¹ 17,256.79	.....	.....	.....
Lincoln.....	2,500.00	.....	.....	2,500	Grand total.....	245,013.65	.....	.....	.....
Lyon.....	21,000.00	27	19,000.00	2,000			.....	.....	.....

¹ Expended from county bond issue.

NEW MEXICO.

TABLE 44.—Revenue applied to roads and bridges, 1914.

County.	Total revenue applied to roads and bridges.	General State and county tax, roads and bridges. ¹		Other revenue applied to roads and bridges.			
		Combined rate, State and county, mills per \$1.	Amount.	Forest reserve fund. ²	Special bridge tax.	Personal tax (\$3).	County levy for special roads.
Bernalillo.....	\$28,859.07	4	\$24,739.73	\$111.35	\$200.99	\$3,807.00	.....
Chaves.....	25,166.63	4	24,862.18	71.10	233.35	.....	.....
Colfax.....	50,621.58	4	22,406.23	24.20	12,720.00	10,114.65	5,356.50
Curry.....	4,926.74	4	4,548.24	.....	.....	378.50	.....
Dona Ana.....	68,343.55	4	65,627.07	.....	440.00	.....	2,276.48
Eddy.....	12,291.88	4	6,824.64	22.35	4,648.76	796.13	.....
Grant.....	45,527.97	4	33,306.24	2,236.96	.....	9,984.77	.....
Guadalupe.....	8,520.12	4	8,520.12	.....	.....	.....	.....
Lincoln.....	13,724.20	4	12,161.18	564.27	.....	998.75	.....
Luna.....	15,832.13	4	14,288.68	.....	.....	1,543.45	.....
McKinley.....	27,204.48	4	19,187.03	1,307.45	.....	6,710.00	.....
Mora.....	17,618.39	4	15,020.72	277.67	.....	.....	2,320.00
Otero.....	15,973.31	4	12,610.12	866.04	.....	483.00	2,014.15
Quay.....	5,227.41	4	5,224.41	.....	.....	3.00	.....
Rio Arriba.....	10,826.97	4	6,801.42	2,731.21	.....	1,294.34	.....
Roosevelt.....	5,114.88	4	4,970.88	.....	.....	144.00	.....
Sandoval.....	4,361.99	4	3,981.89	380.10	.....	.....	.....
San Juan.....	7,500.97	4	4,511.92	.....	2,989.05	.....	.....
San Miguel.....	39,300.17	4	16,316.39	1,168.70	21,126.08	684.00	5.00
Santa Fe.....	12,255.76	4	8,018.38	431.69	3,452.69	133.00	220.00
Sierra.....	7,754.29	4	6,276.44	631.75	.....	846.10	.....
Socorro.....	27,934.26	4	9,988.31	3,994.54	8,085.94	3,761.90	2,103.57
Taos.....	6,069.75	4	4,967.71	1,102.04	.....	.....	.....
Torrance.....	5,493.52	4	5,140.53	343.99	.....	9.00	.....
Union.....	7,872.64	4	7,848.64	.....	.....	24.00	.....
Valencia.....	36,076.16	4	9,806.05	606.28	9,423.60	565.05	15,675.18
Total.....	510,398.82	.....	357,955.15	16,871.69	63,320.46	42,280.64	29,970.88
	³ 16,000.00	.....	.....	.....	.....	.....	.....
	⁴ 30,000.00	.....	.....	.....	.....	.....	.....
Grand total...	556,398.82	.....	.....	.....	.....	.....	.....

¹ State tax 1 mill, county 3 mills.

² The "forest reserve fund" is applied to roads and schools, but there is no way of dividing the amounts.

³ Expended by State from automobile licenses.

⁴ Expended from bond-issue funds in Dona Ana County.

NORTH DAKOTA.

TABLE 45.—Revenue applied to roads and bridges, 1914.

County.	Total revenue applied to roads and bridges.	General county and township tax.	Other revenues applied to roads and bridges.				Labor tax.			
			Auto license.	Poll tax.	Amount.	Miscellaneous source.	Number of men who worked.	Average number of days worked.	Average daily wage.	Cash value of labor tax.
Adams.....	\$27,352.90	\$20,555.00	\$209.40	\$960.00	{ \$145.00 715.00	Emergency and donation fund. Special road and bridge fund.	{ 351	4½	\$3.00	\$4,738.50
Barnes.....	65,901.69	56,070.47	1,983.40	2,500.00	{ 5,467.82	do.	{ }			
Benson.....	74,719.00	57,368.00	985.00	1,700.00	{ 35.00	Emergency and donation fund. Special road and bridge fund.	{ 310	14	3.00	13,020.00
Billings.....	18,174.37	12,273.36	187.60	1,500.00	{ 4,213.41	do.	{ }			
Bottineau.....	97,445.50	87,914.00	1,473.00	2,500.00	{ 1,115.00 2,216.00	Emergency and donation fund. Special road and bridge fund.	{ 198	2½	4.50	2,227.50
Bowman.....	8,297.40	4,500.00	279.40	1,200.00	{ 698.00	do.	{ 135	4	3.00	1,620.00
Burke.....	40,177.70	36,200.00	682.20	1,400.00	{ 101.50	Emergency and donation fund. Special road and bridge fund.	{ 72	3½	3.00	756.00
Burlleigh.....	63,458.20	46,000.00	858.20	1,600.00	{ 1,058.00	do.	{ }			
Cass.....	133,311.60	125,000.00	3,811.60	4,500.00	{ 15,000.00	do.	{ }			
Cavalier.....	85,244.74	79,063.00	1,285.40	2,000.00	{ 75.00 1,567.34	Emergency and donation fund. Special road and bridge fund.	{ 152	3	2.75	1,254.00
Dickey.....	24,173.75	21,812.55	961.20	1,400.00	{ }	do.	{ }			
Divide.....	38,760.00	36,700.00	480.00	1,600.00	{ }	Special road and bridge fund.	{ }			
Dunn.....	21,378.20	17,150.00	188.20	1,300.00	{ 2,740.00	Emergency and donation fund. Special road and bridge fund.	{ }			
Eddy.....	37,899.20	35,690.00	383.20	700.00	{ 776.00	do.	{ }			
Emmons.....	42,835.40	24,873.00	489.40	1,500.00	{ 350.00	Special road and bridge fund.	{ }			
Foster.....	36,493.80	31,000.00	593.80	900.00	{ 15,973.00	Emergency and donation fund. Special road and bridge fund.	{ }			
Golden Valley.....	17,404.40	14,800.00	574.40	1,000.00	{ 4,000.00	do.	{ }			
Grand Forks.....	95,559.00	79,000.00	2,559.00	4,000.00	{ 250.00	Emergency and donation fund. Special road and bridge fund.	{ }			
Griggs.....	37,963.80	31,000.00	963.80	1,000.00	{ 780.00	do.	{ }			
Hettinger.....	39,476.80	29,000.00	276.80	1,200.00	{ 10,000.00	do.	{ }			
Kidder.....	34,068.80	17,500.00	368.80	1,200.00	{ 5,000.00	do.	{ }			
La Moure.....	44,453.75	39,854.75	1,314.00	1,700.00	{ 9,000.00	do.	{ }			
Logan.....	23,737.80	21,810.00	297.80	900.00	{ 15,000.00	do.	{ }			
McHenry.....	85,149.60	80,500.00	1,149.60	2,500.00	{ 1,585.00	do.	{ }			
McIntosh.....	17,258.20	16,000.00	258.20	1,000.00	{ }	do.	{ }			
McLean.....	35,458.14	29,272.34	685.80	2,400.00	{ 3,100.00	Special road and bridge fund.	{ 250	2	2.00	1,000.00
McKenzie.....	18,303.40	16,000.00	303.40	2,000.00	{ }	do.	{ }			
Mercer.....	30,488.78	29,348.38	240.40	900.00	{ }	do.	{ }			

NORTH DAKOTA—Continued.

TABLE 45.—Revenue applied to roads and bridges, 1914—Continued.

County.	Total revenue applied to roads and bridges.	General county and township tax.	Other revenues applied to roads and bridges.					Labor tax.		
			Auto license.	Poll tax.	Amount.	Miscellaneous source.	Number of men who worked.	Average number of days labor worked.	Average daily wage.	Cash value of labor tax.
Morton.....	93,569.60	45,000.00	1,069.60	3,500.00	44,000.00	Special road and bridge fund.....	352	8	.....	.....
Mountrail.....	48,772.80	36,629.00	395.80	2,000.00	238.00	Emergency and donation fund.....			3.00	8,448.00
Nelson.....	38,107.78	35,428.78	1,079.00	1,600.00	1,062.00	Special road and bridge fund.....			.....	.....
Oliver.....	19,516.65	18,288.65	99.00	700.00	429.00	Special road and bridge fund.....			.....	.....
Pembina.....	48,207.60	43,000.00	1,207.60	2,000.00	2,000.00	do.....			.....	.....
Pierce.....	39,438.90	34,848.00	515.40	1,200.00	635.00	Emergency and donation fund.....	94	7	1.75	1,151.50
Ramsey.....	55,171.40	44,000.00	1,171.40	2,000.00	1,089.00	Special road and bridge fund.....			.....	.....
Ransom.....	25,251.40	23,000.00	851.40	1,400.00	8,000.00	do.....			.....	.....
Renville.....	33,880.80	32,129.00	551.80	1,200.00	200.00	Emergency and donation fund.....	193	3	4.00	2,316.00
Richland.....	81,105.91	72,797.00	2,136.60	867.31	2,789.00	Special road and bridge fund.....			.....	.....
Rolette.....	21,612.24	20,000.00	389.60	1,222.64	1,260.00	Special road and bridge fund.....	99	4	3.00	1,188.00
Sargent.....	38,142.00	33,335.00	959.00	1,400.00	691.00	Special road and bridge fund.....			.....	.....
Sioux.....	23,987.20	21,800.00	296.20	1,200.00	12,082.69	Special road and bridge fund.....	305	5	1.77	2,699.25
Sheridan.....	2,699.25	40,398.59	793.80	1,700.00	8,000.00	do.....			.....	.....
Stark.....	54,975.08	10,300.00	812.80	1,000.00	10,000.00	do.....			.....	.....
Steele.....	20,112.80	79,000.00	1,440.20	3,000.00	5,424.82	do.....			.....	.....
Stutsman.....	93,446.20	40,637.22	799.00	1,300.00	3,000.00	do.....			.....	.....
Towner.....	48,161.04	26,100.00	1,632.80	1,600.00	2,016.00	Special road and bridge fund.....			.....	.....
Trail.....	32,332.80	61,218.42	1,574.60	2,500.00	253.00	Emergency and donation fund.....			.....	.....
Walsh.....	65,293.02	80,000.00	1,505.00	3,000.00	1,755.00	Special road and bridge fund.....	168	3	4.50	2,268.00
Ward.....	86,521.00	44,229.13	1,044.40	43.00		do.....			.....	.....
Wells.....	51,316.53	77,996.00	927.20	2,600.00	214,283.58	Special road and bridge fund.....			.....	.....
Williams.....	85,799.20								.....	.....
Total.....	2,402,383.52	2,016,419.64	44,900.60	84,092.95						42,686.75

NOTE.—Sioux County, newly organized, with no separate data available for 1914, is included in Morton County; Slope County, for the same reason, is included in Billings County.

OHIO.

TABLE 46.—*Revenue applied to roads and bridges outside of incorporated cities, 1914.*

County.	Total revenue applied to roads and bridges.	General county and township tax.	State-aid fund to counties.	Other revenue.	
				Amount.	Source.
Adams.....	\$20,434.75	\$13,748.41	\$6,686.34	.....	
Allen.....	127,246.29	112,008.46	15,237.83	.....	
Ashland.....	9,669.09	8,436.05	1,233.04	.....	
Ashtabula.....	35,708.71	35,095.28	613.43	.....	
Athens.....	36,495.66	27,062.50	9,433.16	.....	
Auglaize.....	55,563.09	27,119.70	3,443.39	\$25,000.00	Special assessment.
Belmont.....	108,400.32	¹ 49,933.00	58,467.32	.....	
Brown.....	16,716.89	15,310.98	1,405.91	.....	
Butler.....	12,257.29	11,940.69	316.60	.....	
Carroll.....	25,343.82	25,257.45	86.37	.....	
Champaign.....	30,210.26	19,830.00	10,380.26	.....	
Clark.....	69,092.99	64,702.61	4,390.38	.....	
Clermont.....	63,854.46	¹ 62,708.00	1,146.46	.....	
Clinton.....	24,795.00	24,795.00	.....	.....	
Columbiana.....	17,102.41	12,000.00	5,102.41	.....	
Coshocton.....	11,932.81	11,918.41	14.40	.....	
Crawford.....	18,435.95	17,449.49	986.46	.....	
Cuyahoga.....	¹ 1,120,911.00	¹ 1,120,886.00	25.00	.....	
Darke.....	14,361.69	14,237.19	124.50	.....	
Defiance.....	21,289.92	14,371.60	5,218.32	1,700.00	Donations.
Delaware.....	45,942.45	45,000.00	942.45	.....	
Erie.....	33,693.76	23,500.00	10,193.76	.....	
Fairfield.....	50,908.91	50,908.91	.....	.....	
Fayette.....	18,638.27	10,400.00	8,238.27	.....	
Franklin.....	105,010.32	² 68,386.64	.....	.....	
Fulton.....	90,311.83	25,000.00	11,623.68	.....	
Gallia.....	9,563.64	¹ 72,553.00	1,895.75	15,863.08	Special assessment.
Geauga.....	39,898.04	6,681.00	2,882.64	.....	
Greene.....	95,040.91	35,000.00	4,898.04	.....	
Guernsey.....	63,874.65	¹ 85,434.00	9,606.91	.....	
Hamilton.....	290,429.36	² 30,000.00	4,604.22	.....	
Hancock.....	107,369.19	29,270.43	4,604.22	.....	
Hardin.....	55,433.81	287,042.00	3,387.36	.....	
Harrison.....	50,384.78	106,000.00	1,369.19	.....	
Henry.....	21,916.28	¹ 50,494.00	4,939.81	16,000.00	State highway.
Highland.....	26,321.03	20,100.00	14,284.78	.....	
Hocking.....	14,781.98	21,301.94	614.34	.....	
Holmes.....	8,159.24	24,204.00	2,117.03	.....	
Huron.....	69,805.33	5,228.18	2,040.73	7,513.07	Special tax.
Jackson.....	11,044.40	8,090.69	68.55	.....	
Jefferson.....	124,739.71	24,189.43	45,615.90	.....	
Knox.....	37,740.34	10,562.00	482.40	.....	
Lake.....	77,653.33	¹ 123,324.00	1,415.71	.....	
Lawrence.....	74,655.83	37,728.34	12.00	.....	
Licking.....	73,151.68	² 26,431.16	26,000.00	16,601.61	Other sources.
Logan.....	52,381.51	8,620.56	.....	.....	
Lorain.....	89,467.65	40,000.00	2,155.83	30,000.00	Do.
Lucas.....	219,576.00	21,850.00	49,951.68	2,500.00	Automobile tax.
Madison.....	48,138.93	52,198.87	182.64	1,350.00	Special road tax.
Mahoning.....	117,003.01	² 3,752.55	36,209.32	.....	
Marion.....	20,953.25	49,505.78	42.00	.....	
Medina.....	65,364.39	¹ 219,534.00	.....	.....	
Meigs.....	3,704.01	² 48,138.93	2,806.99	30,000.00	Other sources.
Mercer.....	12,547.60	² 84,196.02	935.49	.....	
Miami.....	380,072.12	20,017.76	.....	.....	
Monroe.....	15,767.95	² 21,870.00	19,994.39	.....	
Montgomery.....	124,660.22	23,500.00	.....	.....	
Morgan.....	9,529.60	3,497.12	206.89	.....	
Morrow.....	2,982.00	2,659.20	9,888.40	.....	
Muskingum.....	102,272.16	44,000.00	72.12	16,000.00	General.
Noble.....	50,357.60	15,689.11	78.84	320,000.00	Emergency bridge funds.
Ottawa.....	19,977.41	79,535.50	42,455.72	.....	
Paulding.....	105,610.85	9,294.27	235.33	.....	
Pickaway.....	37,891.28	2,964.00	18.00	.....	
Perry.....	36,815.95	¹ 57,594.00	44,678.16	.....	
Pike.....	11,878.13	16,811.93	1,545.67	32,000.00	Other sources.
Portage.....	119,676.23	7,568.63	12,408.78	.....	
Preble.....	62,912.87	15,200.00	410.85	90,000.00	Special levy on benefited land.
		23,751.88	14,139.40	.....	
		¹ 36,763.00	62.95	.....	
		4,425.49	7,452.64	.....	
		98,514.80	21,161.43	.....	
		57,450.00	2,962.87	2,500.00	Repair fund.

¹ Expenditures for the year 1913, taken from Bulletin No. 23, State Highway Department.² Township.³ Incorporated township.

OHIO—Continued.

TABLE 46.—Revenue applied to roads and bridges outside of incorporated cities, 1914—Continued.

County.	Total revenue applied to roads and bridges.	General county and township tax.	State-aid fund to counties.	Other revenue.	
				Amount.	Source.
Putnam.....	\$108,965.10	\$98,313.00	\$10,652.10	.....	
Richland.....	42,890.46	38,000.00	4,890.46	.....	
Ross.....	41,507.58	30,390.00	11,117.58	.....	
Sandusky.....	33,765.07	21,103.95	12,661.12	.....	
Scioto.....	178,306.13	55,500.00	11,806.13	\$111,000.00	Special road tax.
Seneca.....	35,191.65	34,463.59	728.06	.....	
Shelby.....	33,886.00	33,868.00	18.00	.....	
Stark.....	292,942.22	¹ 292,172.00	770.22	.....	
Summit.....	104,638.22	27,210.00	45,435.39	31,992.83	Special assessments.
Trumbull.....	111,191.83	29,218.00	81,973.83	.....	
Tuscarawas.....	147,605.17	137,240.00	8,137.17	2,228.00	Collected from property owners.
Union.....	51,717.00	51,693.00	24.00	.....	
Van Wert.....	3,783.75	3,479.00	304.75	.....	
Vinton.....	26,649.19	¹ 20,292.00	6,357.19	.....	
Warren.....	6,518.00	6,500.00	18.00	.....	
Washington.....	60,090.50	² 20,000.00 29,594.46	10,496.04	.....	
Wayne.....	141,887.27	112,000.00	29,887.27	.....	
Williams.....	12,699.29	5,016.04	7,683.25	.....	
Wood.....	² 110,321.22	² 50,000.00	321.22	60,000.00	Road repair.
Wyandot.....	187,088.45	¹ 185,485.00	1,603.45	.....	
Total.....	6,877,476.29 ² 1,072,413.95 ⁴ 6,384,355.74	5,266,081.98	796,476.72	814,917.59	
Grand total	14,334,245.98	.....	.....	.....	

¹ Expenditures for the year 1913, taken from Bulletin No. 23, State Highway Department.² Township.³ Expenditures by State highway department in addition to disbursements to counties.⁴ Bond money spent 1914.

OREGON.

TABLE 47.—Revenue applied to roads and bridges, 1914.

County.	Total revenue applied to roads and bridges.	General county tax.		Other revenue applied to roads.	
		Rate, mills per \$1.	Amount.	Amount.	Source.
Baker.....	\$51,901.90	.....	.....	\$48,938.49	General fund.
Benton.....	70,287.44	5	\$44,000.00	870.38	United States forest rentals.
Clackamas.....	368,214.85	8	240,000.00	2,093.03	Motor licenses.
Clatsop.....	100,000.00	.....	100,000.00	¹ 26,287.44	Miscellaneous sources.
Columbia.....	175,500.00	9.5	175,500.00	¹ 128,214.85	Do.
Coos.....	220,205.21	.....	² 220,205.21	.....	
Crook.....	128,732.46	3.5	24,385.01	7,930.00	General levy.
Curry.....	38,613.62	.....	22,638.40	¹ 96,417.45	Miscellaneous sources.
Douglas.....	168,500.00	5	167,000.00	2,200.00	United States forest fund.
Gilliam.....	55,000.00	.....	30,000.00	¹ 13,775.22	Miscellaneous sources.
Grant.....	27,639.88	4	23,512.19	300.00	United States forest fund.
Harney.....	23,535.48	3	21,752.92	1,200.00	Motor licenses.
Hood River.....	81,343.38	5	42,400.00	25,000.00	Motor licenses.
Jackson.....	71,236.31	.....	71,236.31	¹ 4,127.69	Miscellaneous sources.
Josephine.....	40,000.00	.....	40,000.00	477.61	United States forest rentals.
Klamath.....	62,550.00	4	60,000.00	463.86	Land sales.
Lake.....	33,800.64	2.1	17,541.45	¹ 38,943.38	Motor licenses.
Lane.....	159,482.09	.....	25,000.00	.....	Miscellaneous sources.
Lincoln.....	71,795.58	7	71,795.58	2,550.00	United States forest rentals.
Linn.....	152,896.89	.....	² 152,896.89	1,951.44	United States forest rentals and land sales.
				619.29	Motor licenses.
				¹ 13,688.46	Miscellaneous sources.
				21,655.45	Special road tax.
				¹ 112,826.64	Miscellaneous sources.

¹ Oregon road expenditure report.² Includes miscellaneous revenue.

OREGON—Continued.

TABLE 47.—Revenue applied to roads and bridges, 1914—Continued.

County.	Total revenue applied to roads and bridges.	General county tax.		Other revenue applied to roads.	
		Rate mills per \$1.	Amount.	Amount.	Source.
Malheur.....	45,103.13	4	41,039.14	{ 1,000.00 1 3,063.99	Motor licenses. Miscellaneous sources.
Marion.....	261,115.13	-----	261,115.13	-----	-----
Morrow.....	28,500.00	2.5	27,000.00	1,500.00	Donations.
Multnomah.....	639,335.07	1.8	600,172.45	{ 27,217.06 11,945.56 4,500.00	Motor licenses. Sale of rock and gravel. Special road tax.
Polk.....	103,593.62	-----	85,000.00	{ 14,093.62 1 5,998.30	Miscellaneous sources. Do.
Sherman.....	31,684.25	3	25,685.95	-----	-----
Tillamook.....	188,539.65	9.8	188,539.65	-----	-----
Umatilla.....	119,556.47	2.5	100,000.00	1 19,556.47	Do.
Union.....	46,236.23	2	30,000.00	1 16,236.23	Do.
Wallowa.....	40,005.91	-----	30,000.00	{ 3,000.00 1 7,005.91	United States forest rentals. Miscellaneous sources.
Wasco.....	54,090.65	3	42,964.08	1 11,126.57	Do.
Washington.....	195,236.83	-----	2 195,236.83	-----	-----
Wheeler.....	20,116.16	5	20,116.16	-----	-----
Yamhill.....	64,729.68	5	62,512.24	{ 43.53 2,173.91	United States forest rentals. Motor licenses.
Total.....	3,939,078.51 3 1,217,817.65 4 248,570.60	-----	3,259,245.59	679,832.92	-----
Grand total..	5,310,466.76	-----	-----	-----	-----

¹ Oregon road expenditure report.² Includes miscellaneous revenue.³ Expended in 1914 from county bond issue funds.⁴ Revenue from State tax applied to roads, 1914. Includes a State appropriation of \$10,000 for salary, office and fixed expenses of the State Highway Engineer.

SOUTH DAKOTA.

TABLE 48.—Revenue applied to roads and bridges, 1914.

County.	Total county and township expenditures from all sources for roads and bridges.	Road and bridge levy, mills per \$1.	County.	Total county and township expenditures from all sources for roads and bridges.	Road and bridge levy, mills per \$1.
Aurora.....	\$13,249.90	.6	Hyde.....	123.00	.05
Beadle.....	20,166.85	.7	Jackson.....	15.00	-----
Bennett.....	181.85	.6	Jerauld.....	12,645.61	.8
Bonhomme.....	42,486.79	1.5	Kingsbury.....	6,146.07	.1
Brookings.....	37,060.77	1.16	Lake.....	6,532.92	.4
Brown.....	45,272.79	.6	Lawrence.....	134,659.20	3
Brule.....	5,570.47	.32	Lincoln.....	41,463.04	1.25
Buffalo.....	3,398.88	1.5	Lyman.....	12,926.57	3.5
Butte.....	50,090.06	4.12	McCook.....	9,227.97	.7
Campbell.....	12,869.43	1	McPherson.....	6,963.83	.9
Charles Mix.....	62,889.96	1.75	Marshall.....	3,501.31	.1
Clark.....	-----	.20	Meade.....	19,434.32	1.5
Clay.....	11,455.10	1.5	Mellette.....	3,508.39	1.2
Codington.....	7,027.64	.6	Miner.....	19,908.67	.58
Corson.....	20,476.28	3	Minnehaha.....	60,995.17	1.32
Custer.....	5,688.82	.8	Moody.....	19,140.42	.5
Davison.....	23,520.62	1.6	Pennington.....	45,141.93	-----
Day.....	12,481.68	.5	Perkins.....	679.02	.8
Deuel.....	12,339.28	1.16	Potter.....	2,301.75	.5
Dewey.....	4,098.15	1.9	Roberts.....	16,019.38	.6
Douglas.....	10,652.62	.4	Sanborn.....	30,495.79	1.3
Edmunds.....	-----	.1	Spink.....	26,174.63	.8
Fall River.....	24,856.64	3	Stanley.....	20,078.46	2.7
Faulk.....	5,054.30	.5	Sully.....	1,774.35	-----
Grant.....	2,209.00	-----	Tripp.....	18,470.18	1.2
Gregory.....	19,896.19	2	Turner.....	29,114.64	1
Haakon.....	-----	-----	Union.....	21,246.62	1.15
Hamlin.....	11,112.98	.5	Walworth.....	13,156.64	1.25
Hand.....	25,567.65	.6	Yankton.....	71,570.87	-----
Hanson.....	23,091.34	1.2	Ziebach.....	2,669.55	1.7
Harding.....	12,785.11	1.5	Total.....	1,217,809.42	-----
Hughes.....	6,510.90	.5			
Hutchinson.....	29,662.09	1			

UTAH.

TABLE 49.—*Revenue applied to roads and bridges, 1914.*

County.	Total revenue applied to roads and bridges.	General county tax.		Other revenue applied to roads and bridges.	
		Rate, mills per \$1.	Amount.	Amount.	Source.
Beaver.....	\$9,932.00	5	\$3,890.00	\$642.00	Poll tax.
Boxelder ¹	26,777.93	1	12,307.26	5,400.00	State and county appropriation.
Cache.....	² 38,262.07	-----	-----	14,470.67	General fund.
Carbon ³	-----	-----	-----	38,262.07	From all sources.
Davis.....	59,257.32	5	33,297.00	25,960.32	General county levy.
Emery.....	11,216.84	3	10,171.75	1,045.09	Forest reserve fund.
Garfield.....	17,094.60	-----	14,594.60	2,500.00	Do.
Grand.....	6,484.13	5	4,612.00	1,872.13	Special road tax, 1 mill.
Iron.....	3,968.86	2	3,968.86	-----	-----
Juab.....	5,316.93	1	5,316.93	-----	-----
Kane.....	3,270.91	5	3,270.91	-----	-----
Millard.....	18,000.00	6	18,000.00	-----	-----
Morgan.....	4,617.13	2.5	4,617.13	-----	-----
Piute.....	2,523.00	-----	2,433.00	90.00	Poll tax.
Rich.....	7,469.09	5	6,253.09	216.00	Do.
Salt Lake.....	182,238.25	-----	-----	1,000.00	General county fund.
San Juan.....	5,378.97	5	4,196.05	1,182.92	Appropriation from the general county tax fund.
Sanpete.....	33,336.65	-----	26,475.44	6,861.21	Forest reserve fund.
Sevier.....	13,683.38	-----	11,883.38	1,800.00	General fund.
Summit ¹	31,320.06	-----	19,021.94	1,800.00	County appropriation.
Tooele.....	² 24,673.17	-----	-----	12,298.12	General fund.
Uintah.....	13,871.10	-----	10,312.53	24,673.17	From all sources.
Utah ³	-----	-----	-----	175.10	Poll tax.
Wasatch.....	15,897.90	-----	5,702.08	3,383.47	General county fund.
Washington.....	6,480.36	-----	4,586.57	150.00	Poll tax.
Wayne.....	4,870.26	3	4,870.26	1,187.26	Forest reserve fund.
Weber.....	92,498.45	5	52,498.45	8,858.56	State and county appropriation.
				360.50	Poll tax.
				251.29	Forest reserve fund.
Total.....	638,439.36	-----	263,561.23	40,000.00	County appropriation.
	⁵ 6,899.27	-----	-----	-----	-----
	⁶ 157,732.00	-----	-----	-----	-----
Grand total	803,070.63	-----	-----	-----	-----

¹ 1915 report; no report available for 1914.² Spent from all sources; no division of expenditures.³ No revenue report received.⁴ Includes appropriation from "General fund."⁵ Expended from county bond issues.⁶ State funds applied to roads.

NOTE.—Duchesne County not created in time for 1914 road report

WASHINGTON.

TABLE 50.—*Revenue applied to roads and bridges, 1914.*

County.	Total revenue applied to roads and bridges.	General State, county, and township tax.	Other revenue applied to roads.	
			Amount.	Source.
Adams.....	\$112,046.29	\$106,945.23	\$5,101.06	Petition assessment.
Asotin.....	37,500.72	37,500.72		
Benton.....	64,850.36	64,850.36		
Chelan.....	133,900.74	133,900.74		
Clallam.....	134,729.60	134,729.60		
Clarke.....	156,061.77	151,061.77	5,000.00	Donations.
Columbia.....	96,041.75	96,041.75		
Cowlitz.....	131,503.34	131,503.34		
Douglas.....	79,495.08	79,495.08		
Ferry.....	39,621.71	39,621.71		
Franklin.....	77,558.39	77,558.39		
Garfield.....	59,624.50	59,624.50		
Grant.....	102,976.49	102,976.49		
Grays Harbor.....	371,598.00	371,598.00		
Island.....	31,068.61	31,068.61		
Jefferson.....	81,075.34	81,075.34		
King.....	1,214,372.56	1,211,827.68	2,544.88	Sale of forest reserve timber.
Kitsap.....	62,834.38	62,834.38		
Kittitas.....	120,759.57	120,759.57		
Klickitat.....	115,286.02	115,286.02		
Lewis.....	293,984.10	276,938.28	17,045.82	Miscellaneous receipts.
Lincoln.....	180,941.94	180,941.94		
Mason.....	79,175.09	79,175.09		
Okanogan.....	88,567.13	88,567.13		
Pacific.....	190,818.25	190,818.25		
Pend Oreille.....	66,599.81	63,658.96	2,940.85	Kaniksu national forest appropriation.
Pierce.....	560,469.67	541,710.74	*18,758.93	Donations to county.
San Juan.....	17,051.83	17,051.83		
Skagit.....	216,233.06	215,688.58	544.48	Miscellaneous sources.
Skamania.....	59,535.60	59,535.60		
Snohomish.....	445,648.81	445,648.81		
Spokane.....	538,049.48	533,478.22	4,571.26	Permanent highway contracts paid by abutting property owners.
Stevens.....	97,870.34	97,870.34		
Thurston.....	141,684.83	141,684.83		
Wahkiakum.....	28,485.36	28,485.36		
Walla Walla.....	132,247.63	132,247.63		
Whatcom.....	427,043.38	228,143.57	198,899.81	Miscellaneous sources.
Whitman.....	278,152.51	271,923.19	6,229.32	Assessments of abutting property.
Yakima.....	325,106.84	325,106.84		
Total.....	7,390,570.88	7,128,934.47	261,636.41	
	¹ 509,146.50			
	² 45,000.00			
Grand total	7,944,717.38			

¹ County and district road bond expenditures, 1914.² State appropriation for maintenance of State highway department.

WISCONSIN.

TABLE 51.—*Revenue applied to roads and bridges, 1914.*

County.	Total revenue applied to roads and bridges.	General county and township tax.	General State tax apportioned to counties.	Number of men who worked out poll tax.	Cash value from poll tax labor levy (\$1.50).
Adams.....	\$45,876.00	\$40,435.00	\$3,923.00	1,008	\$1,512.00
Ashland.....	74,739.00	66,500.00	8,239.00	.....	.....
Barron.....	103,416.00	88,845.00	13,110.00	974	1,461.00
Bayfield.....	130,445.00	123,067.00	7,378.00	.....	.....
Brown.....	184,491.50	154,190.00	27,684.00	1,745	2,617.50
Buffalo.....	103,078.00	91,896.00	9,736.00	964	1,446.00
Burnett.....	53,576.50	48,053.00	3,584.00	1,293	1,939.50
Calumet.....	85,968.00	70,241.00	14,230.00	978	1,467.00
Chippewa.....	151,026.00	134,440.00	15,611.00	650	975.00
Clark.....	150,228.00	132,885.00	15,237.00	1,404	2,106.00
Columbia.....	156,257.00	131,341.00	23,647.00	846	1,269.00
Crawford.....	75,591.00	66,357.00	7,440.00	1,196	1,794.00
Dane.....	346,787.00	270,471.00	73,738.00	1,719	2,578.00
Dodge.....	197,257.00	153,266.00	41,240.00	1,834	2,751.00
Door.....	72,014.00	61,040.00	9,033.00	1,294	1,941.00
Douglas.....	172,922.00	147,190.00	25,687.00	30	45.00
Dunn.....	125,956.00	110,912.00	13,277.00	1,178	1,767.00
Eau Claire.....	66,543.00	51,274.00	14,615.00	436	654.00
Florence.....	26,118.00	23,814.00	2,304.00	.....	.....
Fond du Lac.....	174,882.00	135,661.00	36,383.00	1,892	2,838.00
Forest.....	65,776.00	60,730.00	5,046.00	.....	.....
Grant.....	228,095.00	195,923.00	30,540.00	1,088	1,632.00
Green.....	201,193.00	176,948.00	23,155.00	727	1,090.50
Green Lake.....	58,800.00	46,558.00	11,492.00	500	750.00
Iowa.....	130,560.00	109,964.00	19,309.00	858	1,287.00
Iron.....	51,686.00	47,248.00	4,438.00	.....	.....
Jackson.....	95,120.50	85,640.00	8,384.00	731	1,096.50
Jefferson.....	147,092.00	117,303.00	28,010.00	1,186	1,779.00
Juneau.....	87,600.00	77,878.00	8,087.00	1,090	1,635.00
Kenosha.....	134,411.00	110,650.00	23,761.00	.....	.....
Kewaunee.....	84,996.00	72,593.00	10,258.00	1,430	2,145.00
La Crosse.....	172,456.00	150,219.00	21,298.00	626	939.00
Lafayette.....	121,492.00	99,740.00	20,204.00	1,032	1,548.00
Langlade.....	81,412.00	70,916.00	8,918.00	1,052	1,578.00
Lincoln.....	78,294.00	68,720.00	8,950.00	416	624.00
Manitowoc.....	211,867.00	179,698.00	29,166.00	2,002	3,003.00
Marathon.....	203,437.00	177,012.00	25,414.00	674	1,011.00
Marinette.....	100,450.00	88,056.00	12,394.00	.....	.....
Marquette.....	35,124.50	27,249.00	5,903.00	1,315	1,972.50
Milwaukee.....	914,261.00	636,504.00	277,757.00	.....	.....
Monroe.....	171,999.50	155,004.00	13,937.00	2,039	3,058.50
Oconto.....	106,539.50	94,570.00	10,150.00	1,213	1,819.50
Oneida.....	79,324.00	73,860.00	5,464.00	.....	.....
Outagamie.....	197,325.50	167,882.00	27,657.00	1,191	1,786.50
Ozaukee.....	58,924.50	46,618.00	11,543.00	509	763.50
Pepin.....	44,369.00	39,210.00	3,845.00	876	1,314.00
Pierce.....	119,135.50	105,649.00	11,652.00	1,223	1,834.50
Polk.....	102,711.00	88,658.00	11,518.00	1,690	2,535.00
Portage.....	92,236.50	77,056.00	13,115.00	1,377	2,065.50
Price.....	84,365.50	77,940.00	6,034.00	261	391.50
Racine.....	173,874.00	133,979.00	39,595.00	200	300.00
Richland.....	134,349.00	119,584.00	13,559.00	804	1,206.00
Rock.....	199,385.00	156,454.00	42,931.00	.....	.....
Rusk.....	84,936.00	78,941.00	5,783.00	148	212.00
St. Croix.....	105,753.50	89,068.00	14,917.00	1,179	1,768.50
Sauk.....	233,102.50	207,014.00	24,026.00	1,375	2,062.50
Sawyer.....	58,612.00	54,540.00	4,072.00	.....	.....
Shawano.....	142,630.00	123,937.00	14,214.00	2,986	4,479.00
Sheboygan.....	228,322.00	189,664.00	34,533.00	2,750	4,125.00
Taylor.....	99,913.50	92,849.00	6,733.00	221	331.50
Trempealeau.....	151,145.00	135,875.00	12,636.00	1,756	2,634.00
Vernon.....	140,454.00	121,892.00	15,715.00	1,898	2,847.00
Vilas.....	36,695.00	33,695.00	3,000.00	.....	.....
Walworth.....	136,150.50	106,218.00	29,715.00	145	217.50
Washburn.....	60,416.00	55,499.00	3,870.00	698	1,047.00
Washington.....	95,757.50	74,462.00	13,723.00	1,715	2,572.50
Waukesha.....	135,940.00	106,709.00	28,847.00	256	384.00
Waupaca.....	137,266.00	117,685.00	18,093.00	992	1,488.00
Waushara.....	58,898.50	47,522.00	10,100.00	851	1,276.50

WISCONSIN—Continued.

TABLE 51.—Revenue applied to roads and bridges, 1914—Continued.

County.	Total revenue applied to roads and bridges.	General county and township tax.	General State tax apportioned to counties.	Number of men who worked out poll tax.	Cash value from poll tax labor levy (\$1.50).
Winnebago.....	\$159,345.50	\$123,047.00	\$34,938.00	907	\$1,360.50
Wood.....	101,869.00	86,330.00	15,173.00	244	366.00
Total.....	9,433,039.50 ¹ 87,000.00 ² 320,000.00 ³ 40,201.00	7,882,838.00	1,454,704.00	.....	95,497.50
Grand total.....	9,880,240.50				

¹ Appropriated from State general fund for support of State highway commission.² Local funds left over from 1913 and spent on roads in 1914.³ Bond-money expenditures.

WYOMING.

TABLE 52.—Revenue applied to roads and bridges, 1914.

County.	Total revenue applied to roads and bridges.	
	Amount.	Source.
Albany.....	\$620.00 39,562.00 1,686.60 503.02	Auto licenses. General county fund. Inheritance tax. National forest fund.
Bighorn.....	13,046.61	General county fund.
Campbell.....	9,385.89	Do.
Carbon.....	39,089.82	Do.
Converse.....	8,924.65	Do.
Crook.....	22,266.76	Do.
Fremont.....	19,705.79	Do.
Goshen.....	3,603.90	Do.
Hot Springs.....	6,865.59	Do.
Johnson.....	25,036.27	Do.
Laramie.....	11,184.12	Do.
Lincoln.....	39,150.49 26,186.98	Do. Do.
Natrona.....	525.00 2,000.00 2,500.00	Auto licenses. Poll tax. General county fund.
Niobrara.....	1,907.34 17,692.56	Auto and road licenses. General county fund.
Park.....	1,043.76 412.00	One-half forest reserve fund. Auto licenses.
Platte.....	11,991.60	General county fund and auto tax.
Sheridan.....	30,000.00 3,900.00 1,284.00	General county fund. County road poll tax. Auto licenses.
Sweetwater.....	705.00 213.00 38,000.00	State forest reserve. Inheritance tax. General county fund.
Uinta.....	30,057.69 1,003.98	Do. State allotment.
Washakie.....	2,000.00 576.00	County road tax. Forest reserve and poll tax.
Weston.....	10,584.89	General county fund.
Total.....	423,215.31 ¹ 6,237.00 ² 240,208.85	
Grand total.....	669,661.16	

¹ State appropriation for equipment of State convict camps.² Expended by United States Government for repair and betterments of roads in Yellowstone National Park during fiscal year 1914-15.

APPENDIX C.

The following are tables referred to in the foregoing text giving information as to road bond issues in the States discussed:

ARIZONA.

TABLE 53.—*Road and bridge bonds, 1914.*

County.	Total road and bridge bonds out-standing Jan. 1, 1915.	Bonds voted in 1914.	Bonds sold in 1914.	Interest rate.	Term of bonds sold.	Bonds retired in 1914.
				<i>Per cent.</i>	<i>Years.</i>	
Apache.....	\$145,000	\$125,000	\$125,000	5	30	\$5,000
Greenlee.....	150,000	150,000	150,000			
Total.....	295,000	275,000	275,000			5,000

CALIFORNIA.

TABLE 54.—*Road and bridge bonds, 1914.*

County.	Total road and bridge bonds out-standing Jan. 1, 1915.	Bonds voted in 1914.	Bonds sold in 1914.	Interest rate.	Term of bonds sold.	Bonds retired in 1914.
				<i>Per cent.</i>	<i>Years.</i>	
Colusa.....	\$392,000	\$392,000	\$392,000			
Glenn.....	369,000					
Kern.....	1,074,000					\$23,000
Los Angeles.....	3,500,000					100,000
Monterey.....	¹ 570,000	570,000	¹ 570,000	6	10	
Orange.....	1,285,000					45,000
Sacramento.....	600,000					
San Benito.....	280,000					10,000
San Bernardino.....	² 1,750,000	1,750,000	² 1,750,000	5	22½	
San Diego.....	1,064,000					31,000
San Joaquin.....	1,700,000					50,000
San Mateo.....	1,250,000					
Santa Barbara.....	191,000					12,000
Ventura.....	252,000					
Total.....	14,277,000	2,712,000	³ 2,712,000			271,000
	⁴ 18,000,000					
Grand total.....	32,277,000					

¹ Sold Jan. 5, 1915.

² Sold Feb. 8, 1915.

³ Exclusive of State bonds.

⁴ State road bonds.

IDAHO.

TABLE 55.—County and district road and bridge bonds, 1914.

County.	Total road and bridge bonds outstanding Jan. 1, 1915.	Bonds voted in 1914.	Bonds sold in 1914.	Interest rate.	Term of bonds sold.
				<i>Per cent.</i>	<i>Years.</i>
Bear Lake.....		\$50,000			
Gooding ¹	\$154,000				
Jefferson ¹	120,000				
Lincoln ¹	180,000	100,000	\$100,000	6	20
Madison.....	50,000	50,000	50,000	5½	10-20
Nez Perce.....	100,000	100,000	100,000	5	20
Oneida.....	5,000				
Power.....	125,000	125,000	125,000	6	20
Twin Falls.....	100,000				
Total.....	834,000 2 505,000	425,000	375,000		
Grand total.....	1,339,000				

¹ District bonds.² State bonds.

ILLINOIS.

TABLE 56.—Road and bridge bonds, 1914.

County and township.	Total bonds outstanding Jan. 1, 1915.	Bonds voted in 1914.	Bonds sold in 1914.	Interest rate.	Term of bonds sold.	Bonds retired in 1914.
				<i>Per cent.</i>	<i>Years.</i>	
Christian, Johnson.....		¹ \$17,000.00				
Clay, Hartee.....	² \$1,420.00					\$200.00
Cook.....		¹ 2,000,000.00				
Douglas, Sargent.....	³ 23,000.00					6,000.00
Edgar:						
Embarass.....	³ 24,500.00					4,500.00
Paris.....	³ 130,000.00					20,000.00
Do.....	50,000.00		⁴ 50,000.00	5		
Ross.....	³ 40,000.00		⁴ 40,000.00	15		2,700.00
Iroquois:						
Sheldon.....	⁵ 20,000.00					7,400.00
Belmont.....						5,000.00
Henry, Atkinson.....	² 1,900.00					1,000.00
Jackson, Carbondale.....	³ 35,000.00					
Jefferson, Mount Vernon.....	³ 40,000.00	40,000.00	40,000.00	5	10	
Lawrence:						
Bond.....	² 5,000.00					
Denison.....	³ 30,000.00	35,000.00		5		
Lawrence.....	³ 23,000.00					12,000.00
Lee:						
Harmon.....	² 3,000.00	3,000.00	3,000.00	6	7	
East Grove.....	500.00	500.00	500.00	6	1	
Viola.....	² 10,000.00	10,000.00	10,000.00	6	7	
Madison, St. Jacobs.....	² 8,000.00		⁴ 4,000.00	⁴ 15		1,000.00
Marshall, Hopewell.....	² 2,500.00		2,500.00	5	1, 2, 3, 4, and 5	
Ogle:						
Dement.....	³ 9,000.00					3,000.00
Brookville.....	2,383.25		⁴ 850.00	6	2	
Eagle Point.....	³ 3,665.72					3,591.88
Oregon.....	6,000.00	6,000.00	6,000.00	5	1	
Rockvale.....	⁵ 11,000.00					3,000.00
Woosung.....	³ 3,000.00					3,000.00
Pike.....	² 8,300.00					⁶ 20,556.75
St. Clair.....	² 27,835.00					
Stephenson, Loren.....	² 8,000.00	8,000.00	5,000.00	5 or 6	1 to 8	250.00
Vermilion.....	² 1,500,000.00			4	(⁸)	
Blount.....	² 5,000.00		⁴ 2,500.00	6	1 and 2	
Danville.....	² 86,600.00					37,000.00
Grant.....	³ 3,132.58					3,099.10
Jamaica.....	³ 19,000.00					6,333.00

¹ Voted 1914, but not sold.² Bridge.³ Road.⁴ Voted 1913 and sold 1914.⁵ Road and bridge.⁶ Combined township bond expenditure and bond retirement.⁷ Sale postponed by suit against county.⁸ 20-year serial.

ILLINOIS—Continued.

TABLE 56.—Road and bridge bonds, 1914—Continued.

County and township.	Total bonds outstanding Jan. 1, 1915.	Bonds voted in 1914.	Bonds sold in 1914.	Interest rate.	Term of bonds sold.	Bonds retired in 1914.
Wayne:				<i>Per cent.</i>	<i>Years.</i>	
Massilon.....	² \$2,400.00					
Big Mound.....	² 10,125.00					
Leech.....	³ 4,000.00					\$2,283.61
White.....	⁴ 49,500.00					16,000.00
Whiteside:						
Erie.....	² 7,000.00	¹ \$2,000.00				
Sterling.....	² 13,000.00					3,000.00
Will:						
Custer.....	² 2,000.00					1,000.00
Crete.....	³ 35,000.00					
Washington.....	³ 35,000.00	35,000.00	\$35,000.00	5		
Total.....	798,761.55	3,656,500.00	199,350.00			161,914.34

¹ Voted 1914, but not sold.² Bridge.³ Road.⁴ Road and bridge.

INDIANA.

TABLE 57.—Township road and bridge bonds, 1914.

County.	Total bonds outstanding Jan. 1, 1915.	Bonds voted in 1914.	Bonds sold in 1914.	Interest rate.	Term of bonds sold.	Bonds retired in 1914.
				<i>Per cent.</i>	<i>Years.</i>	
Adams.....	\$612,259.46	\$60,163.17	\$108,984.91	4½		\$127,612.06
Allen.....	700,847.00		527,653.96	4½		25,100.02
Bartholomew.....	282,165.25		78,777.54			66,372.83
Benton.....	710,354.00		152,177.56			130,000.00
Blackford.....	366,648.46	208,254.40	127,401.98	4½	10	53,888.65
Boone.....	232,024.00		89,970.10	4½	10	30,334.15
Brown.....						
Carroll.....	450,283.00	90,118.46	40,351.68	4½	10	80,389.91
Cass.....	683,743.29	108,696.59	108,696.59	4½	10	120,000.00
Clark.....	329,730.00	17,194.00	17,194.00	4½	10	52,645.24
Clay.....	415,604.37	57,600.00	57,995.34	4½	10	86,487.28
Clinton.....	708,203.05	98,160.00	98,160.00	4½	10	122,048.89
Crawford.....	68,759.20	17,820.00	17,820.00	4½	10	14,229.80
Daviess.....	427,389.24		123,136.26	4½	10	88,010.15
Dearborn.....	264,365.12	56,039.74	138,844.16	4½	10-20	23,900.84
Decatur.....	564,847.60		71,457.13			82,816.45
Dekalb.....						
Delaware.....	743,435.00	27,880.00	146,662.50	4½		142,451.07
Dubois.....	194,734.95	10,720.00	12,356.00	4½	20	23,361.32
Elkhart.....	268,000.00	172,635.15	95,154.91	4½	10	16,136.51
Fayette.....	81,060.67		29,936.51	4½	20	8,808.33
Floyd.....	160,440.00	92,320.00	68,602.51	4½	20	5,166.75
Fountain.....	527,443.50		189,314.50	4½	10	64,821.15
Franklin.....	227,159.00	18,180.00	18,354.15	4½	10	27,400.37
Fulton.....	86,739.20	241,180.00	5,360.00	4½		
Gibson.....	557,358.00		52,355.00			76,876.81
Grant.....	857,583.06	133,480.00	272,104.64	4½	10	164,007.56
Greene.....	408,450.50		24,348.30		10	72,968.79
Hamilton.....	410,776.31		69,486.56		10	91,527.03
Hancock.....	196,378.30	46,700.00	56,907.24	4½	1-10	34,945.42
Harrison.....	232,252.00		21,471.40	4½	18	26,627.97
Hendricks.....	390,863.91		67,963.61	4½	10 and 20	62,309.20
Henry.....	86,978.00	111,408.00	54,952.89	4½	10 and 20	7,010.81
Howard.....	862,745.50	325,869.56	341,650.81	4½	10	119,386.10
Huntington.....	456,774.42		204,730.18	4½		76,505.85
Jackson.....	204,572.83		31,961.13	4½	10	47,561.41
Jasper.....	248,410.00		91,749.52	4½	10	34,608.71
Jay.....	359,033.94		49,191.13		10	59,646.33
Jefferson.....	221,193.30	59,738.80	60,345.94	4½	10 and 20	21,873.40
Jennings.....	156,319.64		49,444.85		10	33,153.52
Johnson.....	187,834.30	73,880.00	74,466.79	4½	10	21,320.14
Knox.....	838,040.83		94,330.00	4½	10	257,506.53
Kosciusko.....	12,728.00	31,000.00	4,034.50	4½		1,152.40
Lagrange.....						
Lake.....	3,055,536.81		553,868.50	4½	10	358,514.42
Laporte.....	967,290.10	149,600.00	154,267.52	4½	10 and 20	117,674.04

INDIANA—Continued.

TABLE 57.—Township road and bridge bonds, 1914—Continued.

County.	Total bonds outstanding Jan. 1, 1915.	Bonds voted in 1914.	Bonds sold in 1914.	Interest rate.	Term of bonds sold.	Bonds retired in 1914.
				<i>Per cent.</i>	<i>Years.</i>	
Lawrence.....	\$445,549.64	\$8,000.00	\$54,947.33	4½	5	\$65,689.83
Madison.....	850,549.89	162,700.00	169,754.53	4½	10	152,440.95
Marion.....	144,659.20		41,778.52	4½	10	82,515.17
Marshall.....	189,426.40	193,488.40	152,386.43	4½	20	10,169.24
Martin.....	103,279.00	4,200.00	8,297.14	4½		17,035.70
Miami.....	545,839.88	115,360.00	92,679.16	4½	10	86,004.19
Monroe.....	267,721.19		7,836.00	4½	10	67,826.58
Montgomery.....	793,857.00	136,200.00	177,635.70	4½	10	148,229.60
Morgan.....	396,723.90		35,891.65	4½	10	52,760.65
Newton.....	412,071.90		62,676.53	4½	10-20	64,046.60
Noble.....	12,000.00	17,040.00	12,036.27	4½	10	
Ohio.....	20,141.25	8,400.00				4,279.45
Orange.....	190,125.00		33,700.98			45,000.00
Owen.....	165,659.08		24,754.94			31,804.50
Parke.....	416,549.98	34,559.00	51,916.46	4½	20	79,826.48
Perry.....	66,500.00	70,000.00	6,053.02	4½	20	
Pike.....	156,887.60	23,820.00	30,587.25	4½	20	19,623.82
Porter.....	710,526.50		36,359.18	4½	10	104,918.99
Posey.....	535,111.86	41,000.00	62,206.30	4½		60,807.85
Pulaski.....	332,823.85	71,480.00	56,374.19	4½	20	42,468.15
Putnam.....	646,126.00	155,676.04	155,676.04	4½	10, 20, and 40	102,425.09
Randolph.....	621,221.16		148,300.61	4½	10-	105,559.67
Ripley.....	266,639.00	40,400.00	46,651.25	4½	10	54,397.58
Rush.....	579,937.90	34,500.00	34,599.11	4½	10	99,726.04
St. Joseph.....	659,550.00		90,611.80	4½	10	11,179.43
Scott.....	124,640.86		25,440.00			22,728.42
Shelby.....	293,608.20		91,778.74	4½	10	19,741.17
Spencer.....	81,483.50					14,885.97
Starke.....	283,711.44	42,700.00	58,654.95	4½	10	53,741.87
Steuben.....						
Sullivan.....	714,681.36		95,622.90	4½	10	101,614.78
Switzerland.....	134,546.80		18,560.00		10	10,875.32
Tippecanoe.....	767,826.73	122,400.00	72,372.31	4½		70,000.00
Tipton.....	376,487.00		44,443.23	4½	10	116,403.59
Union.....	44,680.30					9,926.81
Vanderburg.....	345,180.00	156,200.00	157,492.47	4½	10 and 20	39,663.04
Vermilion.....	416,724.00	72,000.00	91,756.09	4½	10	93,597.22
Vigo.....	777,755.68		138,353.10	4½	10	79,949.95
Wabash.....	813,001.00		188,134.52	4½	10	118,903.47
Warren.....	431,770.26		69,511.67		10	72,886.46
Warrick.....	88,107.00		58,185.45			5,451.03
Washington.....	344,323.00		45,405.94	4½	10	52,456.13
Wayne.....	311,088.00	19,000.00	101,743.75	4½	10	43,449.80
Wells.....	631,415.00	77,760.00	83,083.41	4½	10	124,172.70
White.....	449,876.25	77,700.00	78,689.03	4½	10	81,740.00
Whitley.....	179,947.50		174,280.78	4½	10	1,333.97
Total.....	36,957,686.22	3,893,221.31	7,841,711.53			5,719,416.47

INDIANA—Continued.

TABLE 57A.—County road and bridge bonds, 1914.

County.	Total outstanding Jan. 1, 1915.	Bonds voted in 1914.	Bonds sold in 1914.	Interest rate.	Term of bonds sold.	Retired during 1914.
				Per cent.	Years.	
Cass.....	¹ \$130,000.00	.....	.....	.....	.....	.....
Clark.....	² 7,875.00	.....	.....	.....	.....	\$2,625
Dearborn.....	¹ 30,000.00	.....	.....	.....	.....	.....
Decatur.....	¹ 28,000.00	.....	.....	.....	.....	2,600
Delaware.....	¹ 75,387.50	.....	.....	.....	.....	4,075
Fayette.....	¹ 26,000.00	\$10,000	\$10,000	.....	.....	.....
Franklin.....	¹ 75,000.00	75,000	75,000	.....	.....	.....
Fulton.....	¹ 50,000.00	.....	.....	4½	20	.....
Harrison.....	¹ 22,500.00	.....	.....	.....	.....	1,250
Jefferson.....	^{1 2} 82,200.00	.....	.....	.....	.....	5,000
Lake.....	¹ 434,500.00	.....	135,811	.....	.....	81,500
Laporte.....	¹ 159,000.00	.....	.....	.....	.....	11,000
Lawrence.....	¹ 91,000.00	.....	.....	.....	.....	.....
Marion.....	¹ 799,000.00	450,000	450,000	4½	20	1,000
Martin.....	¹ 52,000.00	.....	5,130	.....	.....	5,000
Morgan.....	¹ 26,000.00	.....	.....	.....	.....	13,000
Ohio.....	² 11,900.00	.....	.....	.....	.....	.....
Posey.....	¹ 36,000.00	.....	.....	.....	.....	4,000
Randolph.....	¹ 17,500.00	.....	.....	.....	.....	2,500
Rush.....	² 10,000.00	.....	.....	.....	.....	.....
Scott.....	.....	.....	.....	.....	.....	2,000
Shelby.....	¹ 105,000.00	.....	.....	.....	.....	5,000
Spencer.....	¹ 22,600.00	.....	.....	.....	.....	10,700
St. Joseph.....	¹ 683,000.00	100,000	.....	.....	.....	41,600
Switzerland.....	¹ 4,000.00	.....	.....	.....	.....	1,000
Tippecanoe.....	² 390,000.00	.....	.....	.....	.....	.....
Vigo.....	¹ 607,308.62	.....	.....	.....	.....	25,000
Washington.....	¹ 91,900.00	.....	101,353	.....	.....	10,000
Wayne.....	¹ 40,000.00	.....	.....	.....	.....	20,000
White.....	¹ 30,000.00	.....	.....	.....	.....	.....
Total.....	5,137,671.12	635,000	777,294	.....	.....	237,850

¹ Bridge bonds.² Issued for the purchase of toll roads.³ Road and bridge bonds.

IOWA.

TABLE 58.—Road and bridge bonds, 1914.

County.	Total road and bridge bonds outstanding Jan. 1, 1915.	Bonds voted in 1914.	Bonds sold in 1914.	Rate of interest.	Term of bonds sold.
				Per cent.	Years.
Adams.....	\$12,000	.....	.....	.....	.....
Allamakee.....	22,000	.....	.....	.....	.....
Audubon.....	42,000	.....	.....	4½	.....
Boone.....	60,450	.....	.....	4½	.....
Calhoun.....	40,000	.....	.....	5	.....
Carroll.....	40,000	.....	.....	4	.....
Cass.....	94,000	.....	.....	4½	.....
Cedar.....	20,000	.....	.....	5½	.....
Cherokee.....	25,000	.....	.....	5	.....
Chickasaw.....	28,000	\$28,000	\$28,000	5	15
Clinton.....	57,000	.....	.....	5	.....
Crawford.....	50,000	.....	.....	4½	.....
Davis.....	42,500	.....	.....	4½	.....
Des Moines.....	3,000	.....	.....	.....	.....
Fremont.....	126,000	.....	.....	4½	.....
Iowa.....	68,500	13,500	13,500	5	.....
Jackson.....	137,000	.....	.....	.....	.....
Kossuth.....	72,000	.....	.....	.....	.....
Lee.....	30,000	.....	.....	.....	.....
Lucas.....	31,600	.....	.....	4½	.....
Madison.....	41,068	31,068	31,068	4½	.....
Mahaska.....	29,402	.....	.....	.....	.....
Marion.....	65,000	65,000	65,000	.....	.....
Mills.....	7,000	.....	.....	4½	.....
Page.....	49,260	49,260	49,260	5	5
Polk.....	285,000	130,000	130,000	5	18
Union.....	119,000	60,000	60,000	4½	.....
Wapello.....	77,000	.....	.....	.....	.....
Warren.....	35,000	.....	.....	.....	.....
Winneshek.....	145,000	.....	.....	4	.....
Woodbury.....	21,000	.....	.....	.....	.....
Wright.....	86,000	.....	.....	.....	.....
Total.....	1,960,780	376,828	376,828	.....	.....

MICHIGAN.

TABLE 59.—Road and bridge bonds, 1914.

County and township.	Bonds voted and sold in 1914.	Interest rate.	Term of bonds sold.
		<i>Per cent.</i>	<i>Years.</i>
Alger:			
Burt.....	\$10,000.00	4-5	20
Limestone.....	12,000.00	4-5	20
Rockriver.....	12,000.00	4-5	20
Arenac:			
Turner.....	15,000.00	4-5	20
Berrien.....	130,000.00	4	15-20
St. Joseph.....	45,000.00	4-5	20
Lincoln.....	20,000.00	4-5	20
Royalton.....	30,000.00	4-5	20
Cheboygan.....	37,684.34	4	15-20
Dickinson:			
Felch.....	10,000.00	4-5	20
Genesee.....	111,670.89	4	15-20
Gladwin.....	77,120.00	4	15-20
Grand Traverse:			
Green Lake.....	18,000.00	4-5	20
Paradise.....	27,000.00	4-5	20
Long Lake.....	6,000.00	4-5	20
Whitewater.....	10,000.00	4-5	20
Houghton:			
Portage.....	20,000.00	4-5	20
Iron.....	50,000.00		
Mastadon.....	30,000.00	4-5	20
Kalkaska:			
Clearwater.....	6,000.00	4-5	20
Cold Springs.....	5,000.00	4-5	20
Garfield.....	3,000.00	4-5	20
Kent.....	100,000.00	4	15-20
Lake:			
Sweetwater.....	3,000.00	4-5	20
Pleasant Plains.....	3,000.00	4-5	20
Lapeer:			
Almont.....	60,000.00	4-5	20
Lenawee:			
Ogden.....	30,000.00	4-5	20
Macomb:			
Warren.....	35,000.00	4-5	20
Lake.....	57,000.00	4-5	20
Mason:			
Riverton.....	2,000.00	4-5	20
Custer.....	2,000.00	4-5	20
Freesoil.....	1,000.00	4-5	20
Menominee.....	30,000.00	4	15-20
Midland:			
Ingersoll.....	40,000.00	4-5	20
Mount Haley.....	16,800.00	4-5	20
Jerome.....	6,000.00	4-5	20
Monroe:			
Bedford.....	39,000.00	4-5	20
Whiteford.....	60,000.00	4-5	20
Ida.....	30,000.00	4-5	20
Summerfield.....	35,000.00	4-5	20
Newaygo:			
Wilcox.....	8,000.00	4-5	20
Croton.....	20,000.00	4-5	20
Ontonagon:			
Matchwood.....	10,000.00	4-5	20
McMillan.....	9,200.00	4-5	20
Stannard.....	10,000.00	4-5	20
Interior.....	10,000.00	4-5	20
Rockland.....	28,000.00	4-5	20
Carp Lake.....	20,000.00	4-5	20
Ottawa.....	133,506.00	4	15-20
Saginaw:			
Buena Vista.....	20,000.00	4-5	20
Blumfield.....	4,000.00	4-5	20
Frankenhust.....	40,000.00	4-5	20
Birch Run.....	20,000.00	4-5	20
Saginaw.....	10,000.00	4-5	20
Thomastown.....	7,500.00	4-5	20
Schoolcraft:			
Hiawatha.....	4,000.00	4-5	20
Shiawassee:			
Venice.....	30,000.00	4-5	20
Tuscola:			
Denmark.....	12,361.20	4-5	20
Gilford.....	16,900.00	4-5	20
Wayne.....	432,000.00	4	15-20
Total.....	2,080,742.43		

MINNESOTA.

TABLE 60.—Road and bridge bonds, 1914.

County.	Total out- standing road and bridge bonds January 1, 1915.	Bonds voted in 1914.	Bonds sold in 1914.	Interest rate.	Term of bonds sold.	Bonds retired in 1914.
				<i>Per cent.</i>	<i>Years.</i>	
Aitkin.....	\$83,579					
Blue Earth.....	18,000					\$2,000
Carlton.....	46,000					
Cass.....	210,000					
Cook.....	60,000					
Hennepin.....	110,000					
Hubbard.....	77,660					
Itasca.....	381,000		\$300,000	4	20	44,000
Kanabec.....	15,300	\$5,000	5,000	4	10	2,192
Koochiching.....	300,000					
Nicollet.....	50,000	50,000	50,000			
Nobles.....	4,000					
Wadena.....	10,350	3,000	3,000	4	15	1,650
Winona.....	50,000					
Total.....	1,411,889	62,000	358,000			49,842

MISSOURI.

TABLE 61.—Road and bridge bonds, 1914.

County.	Total bonds out- standing January 1, 1915.	Bonds voted in 1914.	Bonds sold in 1914.	Interest rate.	Term of bonds sold.	Bonds retired in 1914.
				<i>Per cent.</i>	<i>Years.</i>	
Callaway.....	\$82,000					\$6,000
Cedar.....	18,500					500
Clinton.....	3,000					
Dade.....	44,000					3,000
Greene.....	7,000					1,500
Grundy.....	5,000			6	10	500
Howell.....	25,000			5		
Jasper.....	25,000	\$25,000	\$25,000	6	2-14	
Lawrence.....	49,000					1,000
Newton.....	30,000					
Nodaway.....	65,000	50,000	50,000	5	5-15	15,000
Pettis.....	169,000					10,000
Total.....	522,500	75,000	75,000			37,500

MONTANA.

TABLE 62.—Road and bridge bonds, 1914.

County.	Total road and bridge bonds out-standing Jan. 1, 1915.	Bonds voted in 1914.	Bonds sold in 1914.	Interest rate.	Term of bonds sold.	Bonds retired in 1914.
				<i>Per cent.</i>	<i>Years.</i>	
Blaine.....	\$40,000.00					
Broadwater.....		¹ \$22,000		5½	20	
Carbon.....	274,000.00					
Cascade.....	45,000.00					
Custer.....	220,000.00					
Dawson.....	100,000.00					
Deer Lodge.....	12,050.72					
Fergus.....	225,000.00	225,000	\$225,000	5	20	\$33,000
Hill.....	100,000.00	100,000	100,000	5	20	
Lewis and Clark.....	105,000.00					
Lincoln.....	125,000.00					
Musselshell.....	120,000.00					
Rosebud.....	117,000.00					
Sanders.....	159,000.00	38,000	38,000	5	20	
Stillwater.....	270,000.00					
Sweet Grass.....	35,000.00					
Teton.....	100,000.00					
Valley.....	65,000.00					
Yellowstone.....	112,000.00	77,000	77,000	5	20	
Total.....	2,224,050.72	462,000	440,000			33,000

¹ Sold early in 1915.

NEVADA.

TABLE 63.—Road and bridge bonds, 1914.

County.	Total road and bridge bonds out-standing Jan. 1, 1915.	Bonds voted in 1914.	Bonds sold in 1914.	Interest rate.	Bonds retired in 1914.	Term of bonds sold.
				<i>Per cent.</i>		<i>Years.</i>
Douglas.....	\$9,000				\$1,000	
Esmeralda.....		\$25,000	\$25,000	6		2 to 6
Ormsby.....	29,000				2,000	
Total.....	38,000	25,000	25,000		3,000	

NEW MEXICO.

TABLE 64.—Road and bridge bonds, 1914.

County.	Total road and bridge bonds out-standing Jan. 1, 1915.	Bonds voted in 1914.	Bonds sold in 1914.	Interest rate.	Term of bonds sold.
				<i>Per cent.</i>	<i>Years.</i>
Dona Ana.....	\$150,000	\$50,000	\$50,000	5	20 to 30
Eddy.....	7,000				
Total.....	157,000	50,000	50,000		

OHIO.

TABLE 65.—Road and bridge bonds, 1914.

County and township.	Total county and township bonds outstanding Jan. 1, 1915.	Bonds retired in 1914.	Bonds voted in 1914.	Bonds sold in 1914.	Interest rate.	Term of bonds sold.
					<i>Per cent.</i>	<i>Years.</i>
Allen.....		\$46,814.00				
Ashland.....	\$60,000.00		¹ \$60,000.00	\$60,000.00		
Ashtabula.....	² 282,322.23 ³ 78,000.00		180,000.00	71,000.00	5	10
Athens.....	² 200,000.00	100,000.00				
Auglaize.....	² 21,000.00 ³ 187,000.00	17,000.00	¹ 17,000.00 ² 50,000.00	17,000.00 50,000.00	5	
Belmont.....	² 405,000.00	45,000.00				
Brown.....	³ 9,500.00					
Butler.....	² 25,000.00 ³ 819,500.00	22,500.00	500,000.00	500,000.00	4½	
Carroll.....	² 10,000.00		10,000.00	10,000.00	5	10
Clark.....	² 30,000.00 ³ 77,500.00	12,500.00	¹ 30,000.00 ² 42,000.00	30,000.00 42,000.00	5	
Clermont.....	² 50,000.00 ³ 135,000.00	12,500.00	¹ 50,000.00 ² 25,000.00	50,000.00 25,000.00	5	1-10
Clinton.....						
Columbiana.....	² 331,250.00 ³ 60,000.00	10,500.00	121,750.00	121,750.00	5	10
Coshocton.....	² 13,198.12 ⁴ 106,277.48	10,000.00	¹ 14,700.00	14,700.00	5	1½
Crawford.....	² 50,000.00		50,000.00	50,000.00	5	
Cuyahoga.....	² 2,683,000.00 ³ 5,010,000.00	³ 335,000.00 ² 263,000.00	650,000.00	650,000.00	5	1-10
Defiance.....	² 128,300.00 ³ 118,000.00	15,960.00	391,000.00	391,000.00	5	1-30
Delaware.....	² 600,000.00 ³ 310,000.00		¹ 144,400.00 ² 100,000.00	144,400.00 100,000.00	5	10
Erie.....	³ 33,500.00	3,000.00	40,000.00	40,000.00	6	2½
Franklin.....	² 1,201,040.00 ³ 308,000.00		394,000.00	394,000.00	5	1-10
Fulton.....	² 231,140.00	52,540.00	143,000.00	143,000.00	5	(⁵)
Gallia.....	² 355,000.00 ³ 34,000.00					
Geauga.....	² 13,000.00 ³ 6,400.00	4,400.00				
Guernsey.....	³ 14,000.00 ² 300,000.00		¹ 6,000.00 ² 8,000.00	6,000.00 8,000.00	5½ 5	8 8
Hamilton.....	¹ 982,138.13 ² 85,000.00	325,000.00	300,000.00	300,000.00	5	10
Hancock.....	² 350,000.00 ³ 20,000.00	25,000.00	85,000.00 97,000.00	85,000.00 97,000.00	5	30
Harrison.....	³ 30,000.00		30,000.00	30,000.00	5	1-10
Henry.....	² 601,600.00 ³ 110,000.00		159,050.00	159,050.00	5	(⁵)
Hocking.....	² 25,000.00	5,000.00				
Holmes.....	² 6,000.00 ³ 41,000.00	8,000.00				
Buron.....	² 78,000.00 ³ 38,000.00		68,000.00	68,000.00	5	1-10
Jackson.....	² 340,000.00	20,000.00				
Knox.....	³ 98,000.00	18,000.00	80,000.00	80,000.00	5	10
Lake.....	² 268,000.00 ³ 14,000.00	10,000.00	¹ 118,000.00	118,000.00	4½	1-20
Leroy.....	² 7,000.00		7,000.00	7,000.00	5	
Madison.....	² 36,000.00		36,000.00	36,000.00	5	
Painesville.....	² 18,000.00		18,000.00	18,000.00	5	2-11½
Willoughby.....	² 39,000.00	4,000.00				
Lawrence.....	² 700,000.00 ³ 40,000.00	15,000.00	100,000.00	100,000.00	5	20
Licking.....	² 500,000.00 ² 250,000.00	136,853.00	95,000.00	95,000.00	5	10
Lorain.....	² 173,000.00 ³ 15,000.00		¹ 136,000.00 ² 37,000.00	136,000.00 37,000.00	4½ 5	8 8
Brighton.....	⁴ 12,000.00					
Columbia.....	65,850.00	1,450.00				
Grafton.....	² 60,000.00					

¹ Issued by county commissioners without vote of people.² Road.³ Bridge.⁴ Road and bridge.⁵ Various.

OHIO—Continued.

TABLE 65.—Road and bridge bonds, 1914—Continued.

County and township.	Total county and township bonds outstanding Jan. 1, 1915.	Bonds retired in 1914.	Bonds voted in 1914.	Bonds sold in 1914.	Interest rate	Term of bonds sold.
					<i>Per cent.</i>	<i>Years.</i>
Lucas.....	{ \$1,277,102.15		{ \$406,905.05	\$406,905.05	5	
Madison.....	{ 382,414.00		{ 181,394.00	181,394.00	5	10
Madison.....	{ 71,000.00		{ 71,000.00	71,000.00	5	
Mahoning.....	{ 294,000.00	\$87,500.00	{ 22,000.00	22,000.00	4½	
Mahoning.....	{ 293,000.00		{ 18,000.00	18,000.00	4½	
Marion.....	{ 299,000.00					
Marion.....	{ 79,500.00	46,696.81				
Medina.....	{ 290,500.00	6,000.00				
Meigs.....	{ 10,000.00	5,000.00				
Mercer.....	{ 450,000.00					
Mercer.....	{ 65,000.00	50,000.00				
Miami.....	{ 266,500.00	{ 31,000.00	300,000.00	300,000.00	5	
Miami.....	{ 485,000.00	{ 10,000.00	61,500.00	61,500.00	5	1-15
Montgomery.....	{ 102,000.00		92,100.00	92,100.00	5	10
Montgomery.....	{ 300,000.00	{ 32,000.00	15,000.00	15,000.00	5	8
Montgomery.....	{ 140,000.00	{ 2,000.00	15,000.00	15,000.00	5	8
Morgan.....	{ 247,500.00		20,000.00	20,000.00	5	
Morgan.....	{ 180,000.00	183,400.00	35,000.00	35,000.00	5	
Morrow.....	{ 159,000.00	42,000.00	159,000.00	159,000.00	5	10
Noble.....	{ 46,000.00	2,000.00				
Noble.....	{ 35,000.00	64,000.00				
Ottawa.....	{ 19,000.00					
Ottawa.....	{ 27,300.00	15,400.00				
Paulding.....	{ 550,000.00	125,000.00	125,000.00	125,000.00	5	6-10
Pickaway.....	{ 262,275.00		{ 126,500.00	26,500.00	5	
Pickaway.....	{ 360,000.00	18,450.00	{ 23,300.00	23,300.00	5	10
Preble.....		27,000.00				
Portage.....	{ 195,500.00		32,500.00	32,500.00	5	
Putnam.....	{ 640,000.00	45,000.00	640,000.00	640,000.00	5	
Richland.....	{ 20,000.00	16,500.00	120,000.00	20,000.00	5	10
Ross.....	{ 280,000.00	4,000.00				
Sandusky.....	{ 245,393.34		32,000.00	32,000.00	5	10
Sandusky.....	{ 22,500.00	39,625.00				
Scioto.....	{ 240,000.00	5,000.00				
Seneca.....	{ 25,000.00		100,000.00	100,000.00	5	6-10
Shelby.....	{ 100,000.00					
Shelby.....	{ 12,250.00	10,750.00				
Shelby.....	{ 85,000.00					
Summit.....	{ 2467,118.08		42,312.58	42,312.58	5	
Summit.....	{ 101,000.00	65,375.00	49,063.00	49,063.00	5	10
Summit.....			46,978.63	46,978.63	5	
Trumbull.....	{ 343,600.00		42,817.20	42,817.20	5	
Trumbull.....			26,600.00	26,600.00	5	
Union.....	{ 133,000.00		317,000.00	317,000.00	5	
Union.....	{ 32,000.00	70,880.00	4,300.00	4,300.00	5	
Washington.....	{ 180,000.00	10,000.00	11,300.00	11,300.00	5	5
Warren.....	{ 310,000.00	8,000.00				
Wayne.....	{ 102,000.00		102,000.00	102,000.00	5	10
Williams.....	{ 16,000.00	3,000.00				
Wood.....	{ 2857,000.00		150,000.00	50,000.00	5	
Wood.....	{ 39,000.00	200,000.00	200,000.00	200,000.00	5	
Wood.....			180,000.00	180,000.00	5	5
Wood.....			24,833.00	24,833.00	5	
Wood.....			16,000.00	16,000.00	5	
Total.....	31,175,968.53	2,684,593.81	8,702,303.46	8,593,303.46		

¹ Issued by county commissioners without vote of people.² Road.³ Bridge.⁴ Road and bridge.⁵ Road, including township.⁶ Township.

OREGON.

TABLE 66.—Road and bridge bonds, 1914.

County.	Total road and bridge bonds outstanding Jan. 1, 1915.	Bonds voted in 1914.	Bonds sold in 1914.	Interest rate.	Term of bonds sold.
				<i>Per cent.</i>	<i>Years.</i>
Clatsop.....	\$400,000	\$400,000	\$400,000	5	20
Columbia.....	360,000	360,000	360,000	5	20
Hood River.....	75,000	75,000	75,000	5	20
Jackson.....	500,000	500,000	500,000	5	10 to 30
Malheur.....	30,000	30,000	30,000	6	20
Multnomah.....	¹ 250,000			5	30
Total.....	1,615,000	1,365,000	1,365,000		

¹ Bridge bonds only.

UTAH.

TABLE 67.—Road and bridge bonds, 1914.

County.	Total road and bridge bonds outstanding Jan. 1, 1915.	Bonds voted in 1914.	Bonds sold in 1914.	Interest rate.	Term of bonds sold.
				<i>Per cent.</i>	<i>Years.</i>
Boxelder.....	\$175,000				
Carbon.....	30,000				
Emery.....	35,000				
Grand.....	19,000	\$10,500	\$10,500	5	20
San Juan.....	14,500				
Uinta.....	8,000				
Total.....	281,500	10,500	10,500		
	¹ 260,000				
Grand total.....	541,500				

¹ State bond issue for construction of State roads and bridges.

WASHINGTON.

TABLE 68.—Road and bridge bonds, 1914.

County.	Total road and bridge bonds outstanding Jan. 1, 1915.	Bonds voted in 1914.	Bonds sold in 1914.	Interest rate.	Term of bonds sold.
				<i>Per cent.</i>	<i>Years.</i>
Asotin.....	\$75,000.00	\$35,000.00	\$35,000.00	5	20
Clallam.....	390,000.00				
King.....	800,000.00				
Okanogan.....		¹ 23,274.27			
Pacific.....	100,000.00				
Wahkiakum.....		¹ 75,000.00			
Total.....	1,365,000.00	133,274.27	35,000.00		
	² 190,000.00				
Grand total.....	1,555,000.00				

¹ Not sold until 1915.² State bonds issued in 1911 for bridge across Columbia River at Wenatchee.

WISCONSIN.

TABLE 69.—Road and bridge bonds, 1914.

County.	Total road and bridge bonds out- standing Jan. 1, 1915.	Bonds voted in 1914.	Bonds sold in 1914.	Interest rate.	Term of bonds sold.	Bond money expended in 1914.	Bonds retired in 1914.
				<i>Per cent.</i>	<i>Years.</i>		
Ashland.....	\$42,500						
Bayfield.....	3,000					\$1,000	\$1,000
Burnett.....	1,600	\$1,500	\$1,500	5	5	1,501	2,250
Clark.....	10,548						
Columbia.....	18,000						
Florence.....	30,000						2,000
Forest.....	3,000						
Grant.....	10,000						
Iron.....	14,000					27,000	7,000
La Crosse.....	12,850					4,000	
Lincoln.....	8,000						
Marathon.....	7,000						
Marinette.....	4,200					700	700
Oneida.....	18,000						
Rusk.....	24,000	20,000	20,000	5	10		
St. Croix.....	1,080						
Sauk.....	12,800					5,000	1,600
Vilas.....	53,000						
Wood.....	7,500						500
Total.....	281,078	21,500	21,500			40,201	16,050

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UNITED STATES DEPARTMENT OF AGRICULTURE



BULLETIN No. 390



Contribution from the Office of Public Roads and Rural
Engineering, LOGAN WALLER PAGE, Director

Washington, D. C.



January 12, 1917

**PUBLIC ROAD MILEAGE AND REVENUES IN THE
UNITED STATES, 1914. A SUMMARY.**

(Based upon Bulletins 386, 387, 388, and 389)

Showing for Each State Total and Surfaced Mileage of Public Roads at the close of 1914, Revenues for Roads and Bridges in 1914, State and Local Road and Bridge Bonds Outstanding on January 1, 1915, and Other Related Data.

PREPARED JOINTLY BY THE DIVISION OF ROAD ECONOMICS OF THE OFFICE OF PUBLIC
ROADS AND RURAL ENGINEERING AND STATE COLLABORATORS.

INTRODUCTORY.

In 1904 the Office of Public Roads adopted the policy of conducting at five-year intervals an investigation to determine the mileage of improved and unimproved roads, the revenues for road purposes, and other related data. In accordance with that policy, Bulletin No. 32 of the Office of Public Roads was issued for the calendar year 1904, and Bulletin No. 41 for the calendar year 1909. Both bulletins were based largely on data obtained by correspondence. The investigation made for the year 1914 followed somewhat different lines. A closer cooperation with State highway departments was maintained, and wherever practicable the information was collected directly by collaborators named by the respective State highway departments and acting under specific instructions from this office. This policy was not practicable in connection with earlier bulletins owing to the fact that most of the States then had no established highway departments.

In several of the States, either because no highway departments existed in 1914 or for other reasons, information was collected by this office directly from local authorities. In the course of the investigation it was found necessary to enlist the aid of local and State road associations, chambers of commerce, automobile clubs, postmasters, and private individuals in order to obtain even reasonably complete information. Highway accounting systems and

methods, especially in the local subdivisions of States, are, in general, far from satisfactory. In many places the records were found to be so indefinite or so incomplete that the most careful investigation failed to determine even the bare total of what funds had been expended on roads and bridges during the previous years. At times the memory of some official or employee seemed a better guide than the permanent existing records.

Lack of definite data and records by the local subdivisions is even more pronounced as to road mileage. Hundreds of instances were discovered where the local officials could give no more than a rough estimate, as maps had not been prepared or measurement of the roads been made. This lack of definite information in some of the States accounts for the fact that the total mileage of roads reported in 1914 was considerably greater than in 1909, while the mileage of surfaced roads reported in 1914 was less than the mileage reported for 1909. The data on mileage and revenues from some of the States should, therefore, of necessity, be considered as approximate. The statistics for each State have been checked, as far as practicable, by the collaborators or by the State highway departments, and it is believed that the 1914 investigation is more complete and accurate than either of the former investigations.

For convenient reference and to avoid delay in publication, the information obtained has been prepared for publication in a series of four bulletins, as follows: Middle Atlantic States, Bulletin 386; Southern States, Bulletin 387; New England States, Bulletin 388; and the Central, Mountain, and Pacific States, Bulletin 389.

In this publication the information contained in the foregoing bulletins is summarized and presented in a series of tables, as follows:

GENERAL SUMMARY.

TABLE 1.—Mileage and revenues and the relation of these to area, population, rural population, and assessed valuation, for the United States as a whole.

PUBLIC ROAD REVENUES.

TABLE 2.—Revenues applied to roads and bridges in the various States in 1914, with comparative information for the year 1904. It will be seen from this table that the total revenue applied to roads and bridges in the United States in 1914 amounted to \$240,263,784. This includes State appropriations, motor vehicle registration and license fees, amounts derived from local taxation, and expenditures from State and local bond issues. In 1904 the total revenue applied to this purpose amounted to \$79,623,616, thus showing an increase for the 10-year period of \$160,640,168, or 201.75 per cent.

ANALYSIS OF REVENUES ON VARIOUS BASES.

TABLE 3.—The relation of road and bridge revenue to mileage, area, population, and assessed valuation, 1914 and 1904.

A study of this table will show that, while the revenue available for road purposes increased from \$37.01 per mile in 1904 to \$98.22 per mile in 1914—an increase of 165 per cent—the actual financial burden upon the taxpayers did not increase in the same ratio. This was due to the fact that property values increased during the same period to such an extent that whereas the average tax burden per \$100 of assessed property value was 23 cents in 1904, it had increased to only 35 cents in 1914, an increase of 52 per cent, or less than one-third the rate of increase in the road fund.

ROAD AND BRIDGE BONDS.

TABLE 4.—State and local road and bridge bonds outstanding January 1, 1915.

These amounted to \$344,763,082, comprising \$115,324,500 of State bonds and \$229,438,582 of local bonds. State bonds have been issued in California, Connecticut, Idaho, Maine, Maryland, Massachusetts, New Hampshire, New York, Rhode Island, Utah, and Washington, and were authorized in New Mexico in 1912, but not sold until 1915. The constitutions of Kansas, South Dakota, and Wyoming prohibit these States from participating in works of internal improvement, and consequently, from issuing State bonds.

ROAD MILEAGE.

TABLE 5.—Total and surfaced mileage of roads in the various States, as of January 1, 1915, with comparative information for 1904 and 1909.

It will be seen from this table that on January 1, 1915, there was in the United States a total of 2,445,761 miles of road, of which 257,291.54 miles, or 10.52 per cent, were surfaced. This does not include the streets in incorporated cities and towns. By comparing these figures with those obtained in former investigations, it appears that between 1909 and 1914, 66,824 miles of road were surfaced. (Fig. 1.)

ANALYSIS OF MILEAGE ON VARIOUS BASES.

TABLE 6 shows the relation of total mileage and surfaced mileage to area and rural population for the years 1904, 1909, and 1914.

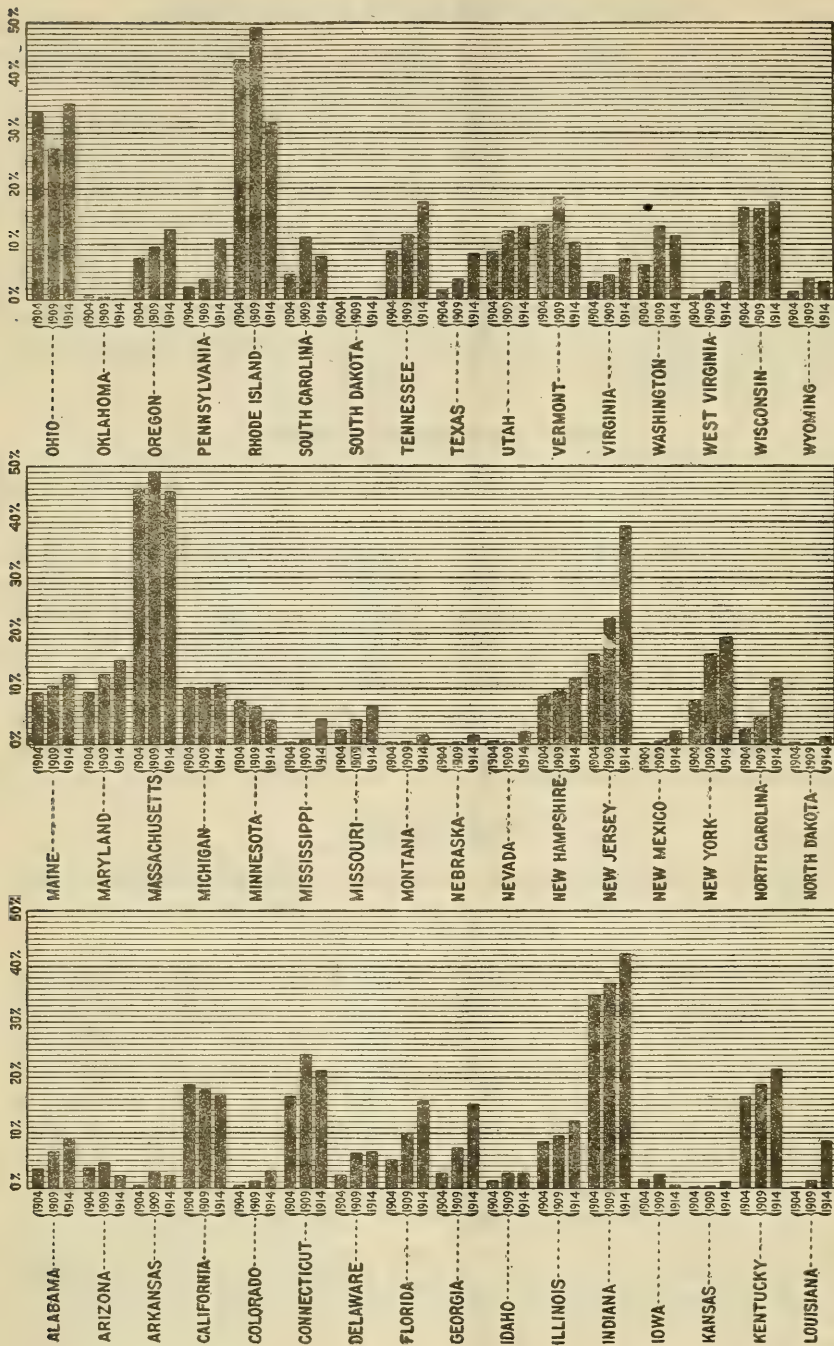


FIG. 1.—Percentage of improved roads in each State—1904, 1909, and 1914.

TYPES OF SURFACED ROADS.

TABLE 7 shows the distribution of types of surfaced roads in the various States on January 1, 1915. Of the 257,291.54 miles of surfaced roads in the United States on January 1, 1915, 116,058.12 miles, or 45.11 per cent, were gravel; 64,898.43 miles, or 25.22 per cent, were macadam; 44,154.73 miles, or 17.16 per cent, were sand clay; 10,499.79 miles, or 4.08 per cent, were bituminous macadam; 2,348.43 miles, or 0.91 per cent, were concrete; 1,593.88 miles, or 0.62 per cent, were brick, and 17,738.16 miles, or 6.90 per cent, were surfaced with various materials.

TABLE 1.—Road mileage, revenue, and other related data for the United States, 1914, 1909, 1904.¹

	1914	1909	1904
Total road mileage.....	2,445,761	2,199,645	2,151,379
Surfaced mileage.....	257,291.54	190,476.32	153,530.4
Percentage surfaced.....	10.5	8.66	7.14
Total revenue.....	\$240,263,784.46	(²)	\$79,623,616.56
State and local road and bridge bonds outstanding Jan. 1, 1915.....	\$344,763,082.32	(²)	(²)
Land area (square miles).....	³ 2,973,830	³ 2,973,830	⁴ 2,974,099
Population.....	³ 91,641,197	³ 91,641,197	⁴ 75,715,857
Rural population.....	³ 49,348,883	³ 49,348,883	⁴ 45,197,390
Assessed valuation.....	⁵ \$69,093,003,851	⁵ \$69,093,003,851	⁶ \$35,114,924,911
Miles of road per square mile of area.....	0.82	0.74	0.72
Miles of road per 1,000 of rural population.....	49.5	44.6	47.6
Surfaced mileage per square mile of area.....	0.086	0.064	0.052
Surfaced mileage per 1,000 of rural population.....	5.21	3.86	3.39
Road and bridge revenue per mile of road.....	\$98.22	(²)	\$37.01
Road and bridge revenue per square mile of area.....	\$80.79	(²)	\$26.77
Road and bridge revenue per capita.....	\$2.62	(²)	\$1.05
Road and bridge revenue per \$100 assessed value....	\$0.35	(²)	\$0.23

¹ Exclusive of District of Columbia, Alaska, and island possessions.

³ 1910.

⁴ 1900.

⁵ 1912.

² No information obtained.

⁶ 1902.

Miles of road surfaced between 1909 and 1914, 66,815.22.

TABLE 2.—Revenue applied to roads and bridges.

States.	Total revenue applied to roads and bridges.		Increase in revenue over 1904.	
	1914	1904	Total increase.	Percent- age of increase.
Alabama.....	\$3,949,019.00	\$1,576,434.27	\$2,372,584.73	150.50
Arizona.....	982,721.22	109,309.43	873,411.79	799.00
Arkansas.....	1,522,696.20	1,395,342.80	127,353.40	9.10
California.....	19,171,984.66	2,157,396.36	17,014,588.30	786.60
Colorado.....	1,937,546.23	707,223.63	1,230,322.60	173.96
Connecticut.....	3,640,962.75	1,195,125.01	2,445,837.74	204.60
Delaware.....	511,628.00	90,802.88	420,825.12	463.40
Florida.....	2,280,255.09	577,577.10	1,702,677.99	294.70
Georgia.....	3,688,172.25	2,080,872.33	1,607,299.92	77.20
Idaho.....	1,371,468.59	311,588.00	1,059,880.59	340.00
Illinois.....	8,734,712.77	4,210,950.23	4,523,762.54	107.42
Indiana.....	14,233,985.93	4,335,108.00	9,898,877.93	228.34
Iowa.....	10,187,507.32	3,106,607.50	7,080,899.82	227.92
Kansas.....	5,544,048.00	1,232,817.45	4,311,230.55	349.70
Kentucky.....	2,474,621.00	2,148,689.03	325,931.97	15.10
Louisiana.....	1,777,572.12	951,872.86	825,699.26	86.70
Maine.....	2,642,006.79	1,472,393.70	1,169,613.09	79.43
Maryland.....	6,000,652.03	873,470.50	5,127,181.53	586.90
Massachusetts.....	6,091,875.30	2,871,222.47	3,220,652.83	112.20
Michigan.....	9,261,998.00	3,179,787.88	6,082,210.12	191.27
Minnesota.....	6,458,940.07	1,961,629.24	4,497,310.83	229.26
Mississippi.....	3,960,377.00	1,675,485.45	2,284,891.55	136.30
Missouri.....	5,513,048.71	2,368,972.79	3,144,075.92	132.72
Montana.....	2,888,400.61	404,097.81	2,484,302.80	614.77
Nebraska.....	1,796,277.69	878,547.40	917,730.29	104.40
Nevada.....	245,013.65	46,875.85	198,137.80	422.68
New Hampshire.....	1,590,464.11	872,606.35	717,857.76	82.20
New Jersey.....	7,208,287.08	3,274,811.25	3,933,475.83	120.00
New Mexico.....	556,398.82	165,651.56	390,747.26	235.88
New York.....	23,231,964.02	5,692,514.82	17,539,449.20	308.00
North Carolina.....	5,215,490.78	1,358,687.00	3,856,803.78	283.80
North Dakota.....	2,402,383.52	550,340.72	1,852,042.80	436.52
Ohio.....	14,334,245.98	5,706,083.61	8,628,162.37	151.23
Oklahoma.....	2,112,680.80	774,775.59	1,337,905.21	172.60
Oregon.....	5,310,466.76	796,375.97	4,514,090.79	566.84
Pennsylvania.....	10,424,580.00	4,887,265.68	5,537,314.32	113.20
Rhode Island.....	446,496.05	405,010.85	41,485.20	10.20
South Carolina.....	1,024,480.37	745,701.50	278,778.87	37.40
South Dakota.....	1,217,809.42	383,283.07	834,526.35	217.73
Tennessee.....	2,370,560.16	1,621,777.15	748,783.01	46.10
Texas.....	9,920,079.11	4,138,157.49	5,781,921.62	139.70
Utah.....	803,070.63	218,675.78	584,394.85	267.24
Vermont.....	1,023,941.01	567,397.33	456,543.68	80.46
Virginia.....	3,224,528.82	687,751.06	2,536,777.76	368.80
Washington.....	7,944,717.38	1,436,070.19	6,508,647.19	453.22
West Virginia.....	2,483,747.00	893,285.28	1,590,461.72	178.00
Wisconsin.....	9,880,240.50	2,181,262.38	7,698,978.12	352.26
Wyoming.....	669,661.16	345,931.73	323,729.43	93.58
Total.....	240,263,784.46	79,623,616.33	160,640,168.13	201.75

TABLE 3.—*Relation of public road and bridge revenues to mileage, area, population, and assessed valuation, 1914 and 1904.*

States.	Revenues.							
	Per mile of road.		Per square mile of area.		Per capita.		Per \$100 of assessed valuation.	
	1914	1904	1914	1904	1914 ¹	1904 ²	1914 ³	1904 ⁴
Alabama.....	\$71.22	\$31.47	\$77.01	\$30.74	\$1.840	\$0.86	\$0.6900	\$0.530
Arizona.....	81.38	18.25	8.63	.96	4.810	.89	.7000	.270
Arkansas.....	30.00	38.28	28.99	26.56	.960	1.06	.3600	.620
California.....	314.09	46.24	123.17	13.82	8.060	1.45	.6600	.170
Colorado.....	48.70	23.40	18.69	6.82	2.420	1.31	.4600	.200
Connecticut.....	258.90	84.84	755.50	248.10	3.260	1.32	.3500	.180
Delaware.....	139.25	30.26	260.37	46.21	2.520	.49	.5450	.131
Florida.....	126.71	33.24	41.56	10.52	3.020	1.09	1.0700	.560
Georgia.....	45.72	36.37	62.80	35.43	1.410	.93	.4370	.440
Idaho.....	56.22	17.15	16.45	3.73	4.210	1.92	.8200	.510
Illinois.....	91.32	44.73	155.85	75.19	1.540	.87	.3700	.410
Indiana.....	194.06	63.46	394.89	120.80	5.270	1.72	.7500	.310
Iowa.....	97.83	30.32	183.27	55.89	4.580	1.39	1.1300	.540
Kansas.....	49.92	12.18	67.79	15.07	3.280	.83	.2000	.340
Kentucky.....	42.52	37.60	61.58	53.47	1.080	1.00	.2390	.300
Louisiana.....	72.37	38.23	39.10	20.96	1.073	.68	.3220	.300
Maine.....	112.25	57.68	88.37	49.29	3.550	2.12	.6330	.418
Maryland.....	364.60	52.07	603.62	87.86	4.630	.73	.4850	.120
Massachusetts.....	326.08	167.99	758.00	357.40	1.810	1.02	.1270	.092
Michigan.....	124.84	45.88	161.13	55.32	3.290	1.31	.4000	.220
Minnesota.....	69.06	24.72	79.88	24.26	3.110	1.12	.4400	.260
Mississippi.....	86.51	43.29	85.42	36.13	2.200	1.08	.9620	.770
Missouri.....	57.40	21.90	80.22	34.47	1.670	.76	.3000	.190
Montana.....	73.67	18.02	19.75	2.76	7.680	1.66	.8300	.220
Nebraska.....	22.37	11.05	23.38	11.43	1.510	.82	.3900	.490
Nevada.....	20.11	3.72	2.23	.42	2.990	1.10	.2400	.160
New Hampshire.....	113.44	57.72	176.11	96.62	3.690	2.12	.3620	.427
New Jersey.....	486.49	220.64	959.00	435.00	2.830	1.73	.2890	.340
New Mexico.....	46.86	10.80	4.54	1.35	1.690	.84	.7700	.430
New York.....	292.60	77.05	467.00	114.00	2.540	.79	.2080	.095
North Carolina.....	102.75	27.30	107.00	27.87	2.360	.71	.6970	.390
North Dakota.....	34.92	9.28	34.23	7.84	4.160	1.72	.6800	.410
Ohio.....	165.99	82.17	351.84	140.06	3.000	1.37	.2200	.290
Oklahoma.....	19.57	17.79	30.45	11.16	1.274	.94	.1769	.870
Oregon.....	144.23	23.24	55.54	8.33	7.890	1.92	.5900	.540
Pennsylvania.....	113.86	48.98	232.00	109.00	1.360	.77	.2050	.124
Rhode Island.....	205.76	171.54	418.50	379.70	.820	.95	.0720	.096
South Carolina.....	24.26	17.82	33.59	24.45	.670	.55	.3510	.380
South Dakota.....	12.64	6.46	15.84	4.98	2.080	.95	.3400	.200
Tennessee.....	51.48	33.10	56.86	38.90	1.080	.80	.3780	.390
Texas.....	76.92	34.08	37.80	15.77	2.540	1.35	.3910	.400
Utah.....	91.15	30.84	9.77	2.66	2.150	.79	.4000	.180
Vermont.....	71.86	39.07	112.22	62.19	2.870	1.65	.4620	.348
Virginia.....	60.39	13.27	80.08	17.08	1.560	.37	.3720	.146
Washington.....	187.25	44.85	118.87	21.48	6.950	2.77	.7900	.550
West Virginia.....	77.55	34.12	103.39	37.18	2.030	.93	.2120	.350
Wisconsin.....	130.50	34.30	178.81	39.47	4.230	1.05	.4000	.140
Wyoming.....	44.06	9.45	6.86	3.54	4.590	1.04	.3700	.790
Weighted averages.....	98.22	37.01	80.79	26.77	2.620	1.05	.3500	.230

¹ Based on the 1910 United States Census.² Based on the 1900 United States Census.³ Based on the 1912 United States Census.⁴ Based on the 1902 United States Census.

TABLE 4.—Road and bridge bonds outstanding January 1, 1915.

State.	Total State and local bonds.	State bonds.	Local bonds.
Alabama.....	\$5,418,000.00	.....	\$5,418,000.00
Arizona.....	295,000.00	.....	295,000.00
Arkansas.....	1,467,066.00	.....	1,467,066.00
California.....	32,277,000.00	\$18,000,000	14,277,000.00
Colorado.....	90,500.00	.....	90,500.00
Connecticut.....	7,000,000.00	7,000,000	(¹)
Delaware.....	1,280,000.00	.....	1,280,000.00
Florida.....	5,959,199.00	.....	5,959,199.00
Georgia.....	127,500.00	.....	127,500.00
Idaho.....	1,339,000.00	505,000	834,000.00
Illinois.....	798,761.55	.....	798,761.55
Indiana.....	42,095,357.34	.....	42,095,357.34
Iowa.....	1,960,780.00	.....	1,960,780.00
Kansas.....	(¹)	(²)	(¹)
Kentucky.....	705,000.00	.....	705,000.00
Louisiana.....	1,588,835.00	.....	1,588,835.00
Maine.....	785,000.00	785,000.00	(¹)
Maryland.....	12,853,700.00	12,410,000	443,700.00
Massachusetts.....	10,305,522.82	8,699,500	1,606,022.82
Michigan.....	10,389,029.43	.....	10,389,029.43
Minnesota.....	1,411,889.00	.....	1,411,889.00
Mississippi.....	8,327,172.00	.....	8,327,172.00
Missouri.....	522,500.00	.....	522,500.00
Montana.....	2,224,050.72	.....	2,224,050.72
Nebraska.....	(¹)	.....	(¹)
Nevada.....	38,000.00	.....	38,000.00
New Hampshire.....	675,000.00	675,000	(¹)
New Jersey.....	14,011,337.00	.....	14,011,337.00
New Mexico.....	157,000.00	(³)	157,000.00
New York.....	76,822,088.00	65,000,000	11,822,088.00
North Carolina.....	8,955,300.00	.....	8,955,300.00
North Dakota.....	(¹)	.....	(¹)
Ohio.....	31,175,968.53	(¹)	31,175,968.53
Oklahoma.....	1,440,000.00	.....	1,440,000.00
Oregon.....	1,615,000.00	.....	1,615,000.00
Pennsylvania.....	27,547,659.00	.....	27,547,659.00
Rhode Island.....	1,800,000.00	1,800,000	(¹)
South Carolina.....	460,000.00	(²)	460,000.00
South Dakota.....	(¹)	.....	(¹)
Tennessee.....	6,898,277.00	.....	6,898,277.00
Texas.....	14,615,017.00	.....	14,615,017.00
Utah.....	541,500.00	260,000	281,500.00
Vermont.....	(¹)	.....	(¹)
Virginia.....	5,650,994.93	.....	5,650,994.93
Washington.....	1,555,000.00	190,000	1,365,000.00
West Virginia ⁴	1,303,000.00	.....	1,303,000.00
Wisconsin.....	281,078.00	.....	281,078.00
Wyoming.....	(¹)	(²)	(¹)
Total.....	344,763,082.32	115,324,500	229,438,582.32

¹ No bonds reported.² Constitution prohibits the State participating in works of internal improvement.³ In 1912 legislature authorized \$500,000 State bonds, but none sold until 1915.⁴ Up to July 1, 1915.

TABLE 5.—Road mileage.

States.	Total road mileage.			Miles surfaced.			Percentage surfaced.			Increase or decrease in miles surfaced, 1909 to 1914.
	1914	1909	1904	1914	1909	1904	1914	1909	1904	
Ala.....	55,446.00	49,639.00	50,089	4,988.50	3,263.93	1,720.00	8.99	6.58	3.43	1,724.57
Ariz.....	12,075.00	5,987.00	5,987	253.43	273.00	217.00	2.09	4.56	3.62	-19.57
Ark.....	50,743.00	36,445.00	36,445	1,097.50	1,085.25	236.00	2.16	2.97	.64	11.75
Cal.....	61,039.00	48,069.00	46,653	10,279.73	8,587.75	8,803.00	16.84	17.87	18.87	1,691.98
Colo.....	39,780.00	29,693.00	30,214	1,193.87	320.50	178.00	3.00	1.08	.59	873.37
Conn.....	14,061.00	12,583.00	14,088	2,975.45	3,080.54	2,360.10	21.16	24.08	16.75	-55.09
Del.....	3,674.00	3,000.00	3,000	243.50	186.44	66.00	6.62	6.22	2.20	57.06
Fla.....	17,995.00	17,579.00	17,374	2,830.47	1,752.35	885.50	15.72	9.97	5.10	1,078.12
Ga.....	80,669.00	82,230.00	57,203	12,342.12	5,978.00	1,634.00	15.30	7.27	2.86	6,364.12
Idaho.....	24,396.00	18,403.00	15,163	679.00	510.50	212.00	2.78	2.77	1.16	168.50
Ill.....	95,647.00	94,141.00	94,141	11,606.81	8,914.00	7,924.00	12.02	9.47	8.42	2,692.31
Ind.....	73,347.00	67,996.00	68,306	30,962.40	24,955.75	23,877.00	42.20	36.70	34.96	6,006.65
Iowa.....	104,074.00	102,427.00	102,448	614.57	2,505.10	1,664.00	.59	2.45	1.62	-1,890.53
Kans.....	111,052.00	98,302.00	101,196	1,148.85	374.71	273.20	1.03	.38	.27	774.14
Ky.....	57,916.00	53,744.00	57,137	12,403.28	10,114.95	9,486.00	21.40	18.82	16.60	2,288.33
La.....	24,563.00	24,962.00	24,897	2,067.62	329.50	34.00	8.42	1.32	.14	1,738.12
Me.....	23,537.00	25,528.00	25,528	2,762.36	2,703.06	2,323.50	11.74	10.59	9.10	59.30
Md.....	16,459.00	16,773.00	16,773	2,489.26	2,142.30	1,570.00	15.10	12.77	9.36	346.96
Mass.....	18,681.00	17,272.00	17,092	8,505.89	8,463.18	7,843.80	45.53	49.00	45.89	42.71
Mich.....	74,190.00	68,906.00	69,296	7,828.51	6,900.54	7,025.50	10.55	10.01	10.14	927.97
Minn.....	93,517.00	79,323.00	79,324	3,967.83	5,416.85	6,247.50	4.24	6.83	7.87	-1,449.02
Miss.....	45,779.00	39,619.00	38,698	2,133.35	342.25	149.00	4.66	.86	.31	1,791.10
Mo.....	96,041.00	107,923.00	108,133	6,712.57	4,755.50	2,733.00	6.98	4.40	2.53	1,957.07
Mont.....	39,204.00	23,319.00	22,419	609.25	95.00	65.00	1.55	.41	.28	514.25
Nebr.....	80,272.00	80,338.00	79,462	1,204.54	248.55	23.00	1.50	.31	.03	955.99
Nev.....	12,182.00	12,751.00	12,585	262.00	46.00	64.00	2.14	.36	.51	216.00
N. H.....	14,020.00	15,116.00	15,116	1,659.63	1,448.48	1,293.00	11.83	9.58	8.55	211.15
N. J.....	14,817.00	14,842.00	14,842	5,897.46	3,377.86	2,422.30	39.80	22.76	16.32	2,519.60
N. Mex.....	11,873.00	16,920.00	15,326	261.50	104.00	2.00	2.20	.61	.01	157.50
N. Y.....	79,398.00	79,279.00	73,798	15,635.90	12,787.36	5,876.00	19.60	16.13	7.96	2,848.54
N. C.....	50,758.00	48,285.00	49,763	6,003.75	2,313.00	1,259.00	11.82	4.79	2.53	3,690.75
N. Dak.....	68,796.00	61,593.00	59,332	955.00	140.00	212.00	1.38	.23	.36	815.00
Ohio.....	86,354.00	88,861.00	69,439	30,569.17	24,106.00	23,460.00	35.16	27.13	33.79	6,463.17
Okla.....	107,916.00	71,325.00	43,554	121.60	361.00	.....	.11	.50	.....	-239.40
Oreg.....	36,819.00	29,475.00	34,258	4,726.40	2,799.25	2,589.00	12.83	9.49	7.56	1,927.15
Pa.....	91,555.84	87,386.79	99,777	9,982.88	3,364.76	2,160.80	10.90	3.84	2.17	6,618.12
R. I.....	2,170.00	2,120.75	2,361	693.42	1,042.07	1,021.50	31.95	49.14	43.27	-348.65
S. C.....	42,226.00	32,075.00	41,830	3,270.50	3,534.75	1,878.00	7.74	11.02	4.49	-264.25
S. Dak.....	96,306.00	56,354.00	59,295	363.00	286.00	151.00	.37	.50	.25	77.00
Tenn.....	46,050.00	45,913.00	48,989	8,102.00	5,353.50	4,285.00	17.59	11.66	8.75	2,748.50
Tex.....	128,960.00	128,971.00	121,409	10,526.79	4,896.00	2,128.00	8.16	3.80	1.75	5,640.00
Utah.....	8,810.00	8,320.00	7,090	1,153.75	1,018.00	608.00	13.09	12.23	8.57	135.75
Vt.....	14,249.00	14,406.00	14,521	1,442.03	2,650.63	1,953.50	10.12	18.40	13.45	-1,208.60
Va.....	53,388.00	43,399.00	51,812	3,909.57	1,902.75	1,600.00	7.32	4.38	3.09	2,006.82
Wash.....	42,428.00	34,283.60	31,998	4,922.09	4,520.68	1,976.50	11.61	13.19	6.17	401.41
W. Va.....	32,024.00	32,109.00	26,178	1,064.97	591.40	254.50	3.30	1.84	.97	473.57
Wis.....	75,707.00	61,090.00	63,593	13,399.47	10,167.33	10,633.20	17.60	16.64	16.72	3,232.14
Wyo.....	14,797.00	10,569.00	10,447	468.50	416.00	153.00	3.10	3.94	1.46	52.50
Total.....	2,445,760.84	2,199,645.14	2,151,379	257,291.54	190,476.32	153,530.40	10.52	8.66	7.14	66,823.93

TABLE 6.—*Relation of total mileage and surfaced mileage to area and rural population.*

States.	Total mileage.						Surfaced mileage.					
	Per square mile of area.			Per 1,000 rural population.			Per square mile of area.			Per 1,000 rural population.		
	1914	1909	1904	1914 ¹	1909 ¹	1904 ²	1914	1909	1904	1914 ¹	1909 ¹	1904 ²
Alabama.....	1.08	0.96	0.97	31.3	28.0	31.5	0.097	0.063	0.033	2.82	1.84	1.06
Arizona.....	.11	.05	.05	85.5	42.4	58.1	.002	.002	.002	1.79	1.93	2.10
Arkansas.....	.96	.69	.67	36.9	26.5	30.3	.02	.02	.004	.80	.79	.196
California.....	.39	.31	.29	67.2	52.9	65.9	.066	.055	.056	11.32	9.46	12.45
Colorado.....	.38	.28	.30	100.9	75.3	108.3	.011	.003	.002	3.02	.81	.64
Connecticut.....	2.92	2.61	2.92	122.3	109.5	121.7	.617	.629	.490	25.89	26.39	20.39
Delaware.....	1.86	1.53	1.53	34.9	28.5	30.3	1.24	.095	.03	2.32	1.77	.667
Florida.....	.33	.32	.31	33.6	32.9	41.2	.052	.032	.016	5.29	3.28	2.09
Georgia.....	1.37	1.40	.96	38.9	39.7	30.5	.210	.101	.028	5.96	2.88	.873
Idaho.....	.29	.22	.20	95.4	71.9	119.6	.008	.006	.002	2.65	1.99	1.39
Illinois.....	1.71	1.68	1.60	44.2	43.5	42.6	.207	.159	.141	5.37	4.12	3.59
Indiana.....	2.03	1.88	1.90	47.1	43.6	41.3	.858	.692	.662	19.88	16.02	14.44
Iowa.....	1.87	1.84	1.84	67.3	66.3	61.7	.001	.045	.029	.39	1.62	1.00
Kansas.....	1.35	1.20	1.20	92.7	82.1	88.8	.014	.004	.003	.96	.31	.24
Kentucky.....	1.44	1.33	1.42	33.4	30.9	34.0	.308	.251	.236	7.15	5.83	5.64
Louisiana.....	.54	.55	.54	21.1	21.5	24.5	.05	.007	.0007	1.78	.0234	.0334
Maine.....	.79	.85	.85	65.3	70.7	71.5	.092	.090	.078	7.65	7.49	6.51
Maryland.....	1.65	1.68	1.68	25.8	26.3	28.1	.25	.22	.15	3.90	3.36	2.63
Massachusetts.....	2.32	2.15	2.13	77.5	71.6	71.7	1.058	1.053	.976	35.29	35.11	32.92
Michigan.....	1.29	1.20	1.20	50.0	46.4	47.2	.135	.120	.122	5.28	4.65	4.78
Minnesota.....	1.15	.98	1.00	76.3	68.7	68.7	.036	.066	.077	2.42	4.42	5.42
Mississippi.....	.98	.85	.83	28.8	24.9	27.0	.046	.007	.003	1.84	.215	.104
Missouri.....	1.39	1.57	1.50	50.6	56.9	54.6	.097	.069	.039	3.54	2.51	1.38
Montana.....	.27	.16	.15	161.5	96.1	141.2	.004	.0006	.0004	2.51	.39	.41
Nebraska.....	1.04	1.04	1.00	91.0	91.1	97.6	.001	.003	.0003	1.36	.28	.03
Nevada.....	.11	.12	.11	177.8	186.1	358.1	.002	.0004	.0006	3.82	.67	1.82
New Hampshire.....	1.55	1.67	1.67	79.9	86.2	81.5	.184	.160	.143	9.47	8.25	6.98
New Jersey.....	1.97	1.97	1.97	23.5	23.6	26.7	.784	.45	.32	9.4	5.4	4.4
New Mexico.....	.09	.14	.12	42.3	60.3	91.3	.002	.0008	.0002	.93	.37	.01
New York.....	1.66	1.67	1.54	41.2	41.1	37.4	.328	.268	.12	8.1	6.6	2.98
North Carolina.....	1.04	.99	1.00	26.8	25.5	29.1	.123	.047	.025	3.18	1.22	.087
North Dakota.....	.98	.88	.84	133.8	119.8	200.6	.013	.002	.003	1.86	.27	.71
Ohio.....	2.12	2.18	1.79	41.0	42.2	32.1	.750	.591	.575	14.54	11.47	10.86
Oklahoma.....	1.55	1.02	1.10	80.7	53.3	59.5	.0017	.0052	.000	.0912	.27	.000
Oregon.....	.38	.31	.36	100.6	80.5	122.2	.049	.029	.027	12.89	7.65	9.23
Pennsylvania.....	2.22	1.95	2.21	30.2	28.8	34.9	.22	.075	.048	3.29	1.11	.76
Rhode Island.....	2.03	1.99	2.21	120.8	118.1	112.9	.649	.977	.957	38.59	58.03	48.83
South Carolina.....	1.38	1.05	1.30	32.7	24.8	35.7	.107	.115	.061	2.53	2.74	1.60
South Dakota.....	1.25	.73	.70	189.8	111.1	164.4	.004	.003	.002	.72	.56	.42
Tennessee.....	1.10	1.10	1.17	26.4	26.3	28.9	.194	.128	.102	4.64	3.07	2.52
Texas.....	.49	.49	.46	43.6	43.6	48.0	.401	.186	.081	3.56	1.65	.841
Utah.....	.11	.10	.08	43.9	41.5	41.3	.014	.012	.007	5.76	5.08	3.55
Vermont.....	1.56	1.58	1.59	76.2	77.0	71.0	.158	.291	.214	7.71	14.17	9.55
Virginia.....	1.32	1.07	1.29	33.7	27.3	34.2	.097	.047	.039	2.46	1.20	1.05
Washington.....	.63	.51	.48	79.0	63.9	104.3	.073	.067	.029	9.17	8.43	6.44
West Virginia.....	1.33	1.33	1.06	32.3	32.3	31.4	.044	.002	.001	1.07	.595	.31
Wisconsin.....	1.37	1.10	1.17	56.9	45.9	49.7	.242	.184	.192	10.08	7.64	8.31
Wyoming.....	.15	.11	.10	147.9	102.8	158.5	.005	.004	.0015	4.56	4.05	2.32
Weighted averages.....	.82	.74	.72	49.5	44.6	47.6	.086	.064	.052	5.21	3.06	3.39

¹ Based on the 1910 U. S. Census.² Based on the 1900 U. S. Census.

TABLE 7.—Types of surfaced roads, 1914.

State.	Macadam.	Bitumi- nous macadam.	Gravel.	Sand clay.	Brick.	Con- crete.	Miscella- neous.	Total surfaced.
	<i>Miles.</i>	<i>Miles.</i>	<i>Miles.</i>	<i>Miles.</i>	<i>Miles.</i>	<i>Miles.</i>	<i>Miles.</i>	<i>Miles.</i>
Alabama	431.00	31.00	2,589.50	1,916.00		1.00	20.00	4,988.50
Arizona	11.23	13.50	125.70	45.00			58.00	253.43
Arkansas	362.50	4.00	535.00	175.00		21.00		1,097.50
California	837.40	877.90	3,563.59	582.25		929.19	3,489.40	10,279.73
Colorado	3.00		574.25	450.12		2.25	164.25	1,193.87
Connecticut	923.42	128.28	1,057.93	840.27	1.33	24.22		2,975.45
Delaware	161.50	35.50	21.00				25.50	243.50
Florida	829.16	42.80	42.50	1,163.00	256.24	12.00	484.77	2,830.47
Georgia	234.00	87.00	1,073.00	10,778.00	1.72	.40	168.00	12,342.12
Idaho	42.50	12.00	168.00	449.00		4.50	3.00	679.00
Illinois	1,675.11	121.53	7,052.30	2,467.95	82.92	148.80	57.70	11,606.31
Indiana	10,291.29	168.35	20,264.59	150.25	34.75	53.17		30,962.40
Iowa	171.30		413.00	23.00		5.77	1.50	614.57
Kansas	194.30		151.85	758.50	4.10	1.35	38.75	1,148.85
Kentucky	10,628.00	59.03	1,713.50		.25	2.50		12,403.28
Louisiana			430.00	1,448.00			189.62	2,067.62
Maine	55.36	43.93	1,139.36	2.26	.05	10.51	1,510.89	2,762.36
Maryland	488.70	1,042.31	243.95	69.00		189.34	455.96	2,489.26
Massachusetts	834.30	1,337.33	6,289.57				44.69	8,505.89
Michigan	1,021.19	94.50	5,230.25	1,375.27		107.30		7,828.51
Minnesota	120.25	19.00	2,825.25	985.33	.50	17.50		3,967.83
Mississippi	86.00	29.50	1,281.10	604.25		14.00	118.50	2,133.35
Missouri	1,531.05	59.00	3,671.50	1,442.25	1.00	2.77	5.00	6,712.57
Montana	78.00		514.25	14.00			3.00	609.25
Nebraska	39.21	1.30	21.00	1,131.10	2.40	7.53	2.00	1,204.54
Nevada	2.00		193.00	67.00				262.00
New Hampshire	61.87	154.26	1,013.70	270.90		7.07	151.83	1,659.63
New Jersey	1,809.24	417.63	2,858.52	561.40			250.67	5,897.46
New Mexico		5.00	184.00	72.50				261.50
New York	5,717.97	3,168.63	5,802.97		148.53	244.19	553.61	15,635.90
North Carolina	1,111.00	9.00	529.00	4,313.50		1.25	40.00	6,003.75
North Dakota			955.00					955.00
Ohio	12,903.87	1,066.29	15,385.93	211.00	640.41	315.67	46.00	30,569.17
Oklahoma	6.70	3.00	6.90	105.00				121.60
Oregon	1,000.72	137.25	3,060.15	300.00		28.41	199.87	4,726.40
Pennsylvania	1,881.80	1,988.33	1,235.19		1,269.33		7,398.23	982.88
Rhode Island	352.92	107.40	230.10				3.00	693.42
South Carolina	27.50	3.50	85.00	3,101.00			53.50	3,270.50
South Dakota		10.00	212.00	129.00			12.00	363.00
Tennessee	4,550.50	148.00	2,788.00	613.00	.50	2.00		8,102.00
Texas	511.00	181.00	5,258.98	3,490.48		11.25	1,074.08	10,526.79
Utah	49.00	15.50	685.75	401.00		2.50		1,153.75
Vermont	1.94		1,165.42				274.67	1,442.03
Virginia	1,177.89	255.77	822.09	1,511.65			142.17	3,909.57
Washington	502.82	165.52	3,924.48	83.50	26.35	79.42	140.00	4,922.09
West Virginia	771.92	62.95	20.50		121.10	18.50	70.00	1,064.97
Wisconsin	1,408.00	183.00	9,597.00	2,054.00	2.40	83.07	72.00	13,399.47
Wyoming			52.50				416.00	468.50
Total	64,898.43	10,499.79	116,058.12	44,154.73	1,593.88	2,348.43	17,738.16	257,291.54
Per cent.	25.22	4.08	45.11	17.16	.62	.91	6.90	100.00

¹ State roads only.

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UNITED STATES DEPARTMENT OF AGRICULTURE



BULLETIN No. 391

Contribution from the Bureau of Chemistry
CARL L. ALSBERG, Chief



Washington, D. C.

PROFESSIONAL PAPER

December 10, 1918

ACCURACY IN COMMERCIAL GRADING OF OPENED EGGS.

By M. K. JENKINS, *Assistant Bacteriologist*, and NORMAN HENDRICKSON, *Assistant Chemist, Food Research Laboratory.*

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INTRODUCTION.

The quality of liquid egg used in making frozen or dried egg products depends upon two factors: First, the character of the eggs entering the product; and, second, the cleanliness of preparation. Eggs, good and bad, as they appear before the candle and out of the shell, with their respective chemical and bacterial characteristics, have been discussed in Bulletin 51.¹ The precautions necessary to insure cleanliness when opening the eggs and collecting their contents to be frozen or dried have been discussed in Bulletin 224,² in which publication much attention is directed also to the character of the eggs used. During the progress of the work the question of the accuracy of grading eggs by sight, smell, and taste frequently arose. It was observed that samples made from comparatively high-grade stock sometimes had a higher bacterial content than could be accounted for on the basis of faulty manipulation. They seldom showed chemical evidence of decomposition. It was ob-

¹ A Bacteriological and Chemical Study of Commercial Eggs in the Producing Districts of the Central West. U. S. Dept. Agr. Bul. 51, 77 p., 8 pl., 2 fig., July 20, 1914.

² A Study of the Preparation of Frozen and Dried Eggs in the Producing Section. U. S. Dept. Agr. Bul. 224, 99 p., 17 pl., 7 fig., Apr. 28, 1916.

served, also, that the lower the grade of the breaking-stock eggs and the more numerous the discards in the breaking room, the higher was the average bacterial count, even though every care was used by the breaker to eliminate unfit eggs. Apparently, then, there are some infected eggs among the cracked eggs, dirty eggs, and stale seconds, which so often go to the egg-breaking plant, which it is either quite impossible or very difficult to detect when grading out of the shell by ordinary means. The questions now to be considered are: What is the character of these eggs, how many bacteria do they contain, and how frequently do they occur?¹

PURPOSE, PLAN, AND EXTENT OF INVESTIGATION.

PURPOSE.

The purpose of the investigation was fourfold:

1. To obtain additional information regarding the bacteriology of individual eggs used in the preparation of frozen and dried eggs.
2. To determine the accuracy of the present methods of grading individual eggs.
3. To find the number and kinds of eggs containing bacteria not detected by the usual grading.
4. To determine the effect of eggs containing bacteria upon composite products as evidenced by the bacterial content and the amount of ammoniacal nitrogen present in the finished product.

PLAN.

The material for study consisted of breaking stock—that is, odd-sized eggs, dirty eggs, cracked eggs, shrunk eggs, and heated eggs. The samples were made up of approximately six dozen eggs each and were purchased in all but a few instances from commission houses located in a large eastern consuming center.

All of the eggs for the experiments were commercially candled by the regular candlers of the commission house, who aimed to reject as unfit for food purposes all eggs containing blood, either in the form of clots or blood rings, all eggs with either broken or adherent yolks, and all addled eggs, and to retain eggs with whole yolks freely moving in the white. Eggs showing signs of incubation prior to the appearance of the blood ring were not discarded.

On receipt at the laboratory each egg in the sample was numbered and described fully. The color, cleanliness, and soundness of the shell were noted. The eggs were recandled and the condition of the white and yolk observed. They were then opened aseptically and placed individually into sterile glass custard cups similar to

¹ The work discussed in this bulletin was done under the direction of Dr. M. E. Pennington, to whom thanks are due for many valuable suggestions. A large part of the routine bacteriological work was done by Dr. E. Q. St. John and Dr. E. Witmer, and the chemical work was performed by E. L. Connolly.

those used in the cooperating egg-breaking plants for holding the eggs during grading. The cups were kept covered to prevent contamination from the air.

In order that the grading might be uniform throughout the investigation and parallel the method followed in the cooperating egg-breaking plants, all of it was done by the same person, who was familiar with commercial procedures. Each egg was graded as good or bad, according to appearance and odor, and in case of doubt was graded also according to taste.

After each egg was graded, a portion was removed to be examined for the number of bacteria and for the presence or absence of members of the *B. coli* group.¹ All of the eggs graded as good were then mixed to form a composite sample, which was examined for the total number of bacteria, the number of organisms producing gas in lactose bile, the percentage of moisture, and the amount of ammoniacal nitrogen as determined by the Folin titration method.

After the egg had been thoroughly mixed, one cubic centimeter was withdrawn.² With this portion dilutions of 1 to 10, 1 to 100, and 1 to 1,000 were made with physiological salt solution. From the three dilutions plates were made with nutrient agar as the medium. One cc of the first dilution was transferred to a fermentation tube containing lactose bile. The plates were incubated at room temperature for 5 days and the fermentation tubes at 37° C. for 2 days. This procedure was followed in the examination of the individual egg. The composite samples were examined according to the methods described in Department Bulletin 51 (pp. 74 to 77). The number of bacteria in the individual eggs is expressed on the cubic-centimeter basis. As an egg which has been frozen for any length of time becomes so thick that it is not possible to deliver definite quantities accurately from a pipette, the portion of frozen egg to be examined was weighed and the results expressed on the gram basis. The two bases are comparable because the specific gravity of the egg after the white and yolk are mixed is practically unity.

EXTENT.

During the course of the study 2,052 individual breaking-stock eggs, representing 29 samples, which varied in size from 66 to 72 eggs, were studied according to the plan just outlined. The samples were procured at fairly regular intervals between May 23 and October 27, 1913, a period which covered the greater part of the egg-breaking season in the consuming center from which the eggs were chosen.

¹ The terms *B. coli*, *B. coli* group, and organisms or bacteria producing gas in lactose bile are used synonymously in this publication.

² For the purpose of this report, eggs which did not show the presence of bacteria in 1 cc have been considered sterile, since a smaller number of bacteria is negligible from the viewpoint of possible food contamination.

HISTORY AND BACTERIAL CONTENT OF SAMPLES.

HISTORY OF SAMPLES.

Most of the samples of breaking-stock eggs used for the investigation were procured from the current receipts of commission houses located in an eastern consuming center. In a few instances in the beginning of the season samples were purchased from grocery stores. Late in the season the samples consisted of breaking-stock eggs sorted from eggs coming from storage. The firms from whom most of the samples were obtained operated egg-breaking plants in addition to their wholesale business. Most of the eggs were produced either in the Middle Western States or in Virginia, and were shipped to the consuming center; after the weather had become warm, in refrigerator cars. The time occupied in making the haul varied from 3 to 12 days. The history of each sample is given in Table I.

TABLE I.—*History of samples.*

Sample No.	Shipped from—	Date shipped.	Date received at commission house.	In storage.	Out of storage.	Date examined.	Kind of eggs.
		1913.	1913.	1913.	1913.	1913.	
41142	Edinburg, Va. . .	May 17	May 20	.....	.....	May 23	Cracked eggs.
41143	Moorestown, N. J. . .	.....	May 27	.....	.....	May 27	Fresh brown-shelled eggs.
41144	Edinburg, Va. . .	May 22	May 26	.....	.....	May 29	Dirty eggs.
41145	do. . .	.....	.....	.....	.....	June 3	Seconds.
1 41146	.....	.....	.....	.....	.....	June 10	Do.
41147	.....	.....	.....	.....	.....	June 12	Grocery eggs.
41148	.....	.....	.....	.....	.....	June 17	Do.
41149	Woodbine, Iowa. . .	June 10	June 18	.....	.....	June 19	Cracked eggs.
41161	Edinburg, Va. . .	June 12	June 16	.....	.....	June 20	Seconds and cracked eggs.
41164	Woodbine, Iowa. . .	June 16	June 23	.....	.....	June 24	Cracked eggs.
41167	Mount Jackson, Va. . .	June 14	June 24	.....	.....	June 26	Seconds.
41169	New Albany, Ind. . .	June 12	June 21	.....	.....	June 27	Do.
41175	New York, N. Y. . .	July 7	July 9	.....	.....	July 10	Seconds and cracked eggs.
41178	Edinburg, Va. . .	July 8	July 11	.....	.....	July 16	Do.
41180	Logan, Iowa. . .	July 7	July 18	.....	.....	July 21	Do.
41182	do. . .	July 14	July 21	.....	.....	July 22	Do.
41185	Edinburg, Va. . .	July 15	July 18	.....	.....	July 23	Do.
41189	do. . .	July 17	July 21	.....	.....	July 25	Do.
41192	do. . .	July 19	July 24	.....	.....	July 29	Do.
41316	Woodbine, Iowa. . .	Aug. 7	Aug. 16	.....	.....	Aug. 18	Do.
41435	Edinburg, Va. . .	Sept. 4	Sept. 8	.....	.....	Sept. 10	Do.
41438	Owatonna, Minn. . .	.....	Sept. 8,9	.....	.....	Sept. 11	Do.
1 41505	.....	.....	.....	.....	.....	Sept. 19	Seconds, cracked, and dirty eggs.
41506	Edinburg, Va. . .	Sept. 20	Sept. 22	.....	.....	Sept. 25	Dirty and cracked eggs.
41509	Decatur, Ind., and Manitowoc, Wis. . .	.....	.....	July 21	Sept. 24	Sept. 26	Do.
41551	Bluffton, Ind. . .	July 19	July 23	July 23	.....	Oct. 3	Seconds, cracked, and dirty eggs.
41645	Harrisonburg, Va. . .	May 5	May 7	May 7	Oct. 14	Oct. 15	Do.
1 41598	.....	.....	.....	Apr. 13	Oct. 13	Oct. 17	Do.
41645	Michigan. . .	Apr. 15	.....	Apr. 22	Oct. 25	Oct. 27	Do.

1 Purchased at commission house; further history unknown.

NUMBER OF EGGS CONTAINING BACTERIA.

Only a few of the individual eggs examined contained appreciable numbers of bacteria. Two lots, Nos. 41192 and 41645, were exceptional in that nearly all the eggs comprising them har-

bored bacteria. Of the 2,052 eggs included in the 29 samples, 13.5 per cent, as computed from Table II, were found to contain more than 100 organisms per cc. The remaining 86.5 per cent contained less than 100 organisms per cc, that is, they were practically sterile. Only 3.3 per cent contained over 500,000 organisms per cc. The percentage of eggs containing *B. coli* (2.8 per cent) was considerably less than the total percentage of the eggs containing bacteria.

A very large percentage of the eggs comprising sample No. 41192 had both dirty and cracked shells. These eggs were laid in July when the weather was very hot. It is highly probable that bacterial penetration and development took place between the time of first assortment in the producing section and final receipt in the consuming center, as an interval of 10 days occurred between the date of shipping and that of grading in the commission house, during a portion of which period the eggs were without refrigeration. Had these eggs been utilized promptly in the first concentrating center, there is little doubt that only a few of them would have been found to contain bacteria. The results obtained in the case of these eggs show the importance of having eggs with defective shells opened as near the source of production as possible.

TABLE II.—*Variation in bacterial content of samples of individual eggs candled as good.*

Sample No.	Date of examination.	Number of eggs.	Number of bacteria per cc.													
			0 to 100.		101 to 1,000.		1,001 to 10,000.		10,001 to 50,000.		50,001 to 100,000.		100,001 to 500,000.		Over 500,000.	
			No. of eggs.	P. ct.	No. of eggs.	P. ct.	No. of eggs.	P. ct.	No. of eggs.	P. ct.	No. of eggs.	P. ct.	No. of eggs.	P. ct.	No. of eggs.	P. ct.
1913.																
41142	May 23	72	71	98.6	1	1.4										
41143	May 27	72	72	100.0												
41144	May 29	72	69	95.8			2	2.8							1	1.4
41145	June 3	70	70	100.0												
41146	June 10	71	67	94.4	1	1.4	1	1.4							2	2.8
41147	June 12	70	67	95.7	2	2.9									1	1.4
41148	June 17	72	71	98.6											1	1.4
41149	June 19	70	54	77.1	5	7.1	2	2.9				3	4.3		6	8.6
41161	June 20	72	69	95.9					1	1.4	1	1.4			1	1.4
41164	June 24	69	67	97.1	1	1.5									1	1.5
41167	June 26	72	71	98.6											1	1.4
41169	June 27	71	67	94.4											4	5.6
41175	July 10	70	61	87.1	3	4.3	1	1.4	3	4.3					2	2.9
41178	July 16	69	66	95.7	1	1.4									2	2.9
41180	July 21	70	57	81.4	7	10.0			1	1.4					5	7.1
41182	July 22	70	64	91.4	3	4.3	1	1.4	1	1.4	1	1.4				
41185	July 23	71	67	94.4	2	2.8	1	1.4							1	1.4
41189	July 25	72	66	91.7	1	1.4						2	2.8		3	4.2
41192	July 29	66			4	6.1	11	16.6	14	21.2	9	13.6	21	31.8	7	10.6
41316	Aug. 18	70	63	90.0	3	4.3	2	2.8							2	2.9
41435	Sept. 10	70	62	88.6	1	1.4	1	1.4	1	1.4					5	7.1
41438	Sept. 11	71	64	90.1	2	2.8							1	1.4	4	5.6
41505	Sept. 19	72	63	87.5	1	1.4			1	1.4	1	1.4			6	8.3
41506	Sept. 25	72	64	88.9	1	1.4	1	1.4	2	2.8	1	1.4			3	4.2
41509	Sept. 26	71	66	93.0	2	2.8									3	4.2
41551	Oct. 3	72	63	87.5	7	9.7	2	2.8								
41594	Oct. 15	71	63	88.7	4	5.6					1	1.4			3	4.2
41598	Oct. 17	72	56	77.8	13	18.1	1	1.4	1	1.4			1	1.4		
41645	Oct. 27	70	14	20.0	11	15.7	19	27.1	11	15.7	6	8.5	4	5.7	5	7.1
Total.....		2,052	1,774	86.5	76	3.7	45	2.2	36	1.7	20	1.0	32	1.5	69	3.4

The eggs composing sample No. 41645 were low-grade seconds and cracked eggs sorted from April storage packed eggs. Although the bacterial findings in these eggs are extreme, they afford a good example of what happens when undergrade stock, particularly cracked eggs, is held in storage for several months. Other investigations confirm the bacterial findings in these grades of eggs.¹

While the actual number of eggs in these two samples is small, they represent grades of eggs which come with more or less frequency to all egg-breaking plants. It is evident that it is not possible to prepare from them a uniformly high-grade product.

The results obtained from the examination of these eggs, as pictured graphically in figure 1, show the condition in which the eggs under observation, which had been candled as fit for food purposes,

2,052 TOTAL NUMBER OF EGGS EXAMINED

86.5 PER CENT, PRACTICALLY STERILE

13.5 PER CENT, CONTAINING BACTERIA

2.8 PER CENT, CONTAINING B. COLI.

FIG. 1.—Results of bacteriological examination of candled breaking stock.

would have reached the consumer had they been sold in the shell. In other words they show the limitations of candling as the only method for determining the condition of market eggs.

It will appear subsequently to what extent the grading of eggs out of the shell is of assistance in the separation of sterile eggs from nonsterile eggs.

It will appear subsequently to what extent the grading of eggs out of the shell is of assistance in the separation of sterile eggs from nonsterile eggs.

EFFECT OF CONDITION OF SHELL UPON BACTERIAL CONTENT OF EGG.

DESCRIPTION OF THE EGG SHELL.

The contents of an egg is protected by a shell and two membranes. The shell, which is composed largely of lime salts, is porous and is coated with a mucilaginous material which gives the bloom characteristic of newly laid eggs. The two elastic membranes which line the shell consist of microscopic fibers very closely interlaced. The outer tissue is much heavier than the inner. The two separate at the large end of the egg and form the upper and lower walls of the air cell. Nature has thus provided a protective porous covering through which the respiration of the chick, during its embryonic development, may proceed. If the shell is not cracked it offers a very effective barrier against mold and bacterial penetration. If it is cracked, however, bacteria can more readily penetrate the two membranes. Egg handlers are familiar with the growth of mold in the crevices of a cracked shell.² In a large number of examinations³ of eggs containing molds, bacteria were found to be present in almost all instances, usually in large numbers. The contents of leaking eggs,

¹ Unpublished results.

² U. S. Dept. Agr. Bul. 51, pl. VI.

³ U. S. Dept. Agr. Bul. 51, pp. 33-48.

that is, eggs in which the shell and both membranes are broken, may become contaminated directly.

It has been stated by Kossowicz¹ that the shells of stale eggs offer less resistance to bacterial and mold invasion than do those of fresh eggs. Even the shells of clean eggs frequently harbor many bacteria and also *B. coli*.²

Experiments have shown that bacteria and molds can penetrate an unbroken shell if it is in a moist condition. Water removes the mucilaginous coating naturally present on the shells and renders the fibrous membrane pervious to organisms. Hen feces and the contents of broken eggs when damp attach themselves to the shell. The dirt then becomes the carrier of the bacteria and the moisture presents the mechanical means necessary for their penetration.

In the second report³ of this series, a general survey of the literature on bacteria in perfectly fresh eggs was given. Since this bulletin was published, Rettger⁴ has discussed the results of the bacteriological examination of 20,000 newly laid eggs. His findings corroborate those of previous investigators, namely, that, with but few exceptions, strictly fresh eggs are sterile; and those which do contain bacteria have them only in small numbers. These bacteria are too few to affect the use of fresh eggs for food, but their presence or absence determines the ideal for eggs. The maintenance of low bacterial contents in eggs and egg products, therefore, is one index of the efficiency of egg-handling operations.

Many examples of eggs with high bacterial content are given in Department Bulletin 51. It is interesting to note that in those eggs in which both the white and yolk were examined, the number of bacteria was markedly greater in the white than in the yolk, a condition indicative of bacterial penetration from the exterior.

EGGS WITH SOUND, CRACKED, AND LEAKING SHELLS.

As a large percentage of the breaking stock of the cooperating egg-breaking plants consisted of eggs with defective shells, a detailed description was made of the condition of the shell of each egg in the 29 experimental samples examined in order to determine the effect of a dirty or damaged shell upon the condition of the contents. The results of this study are given in Table III and in figure 2.

The possibility of bacterial penetration increases with the amount of damage to the shell. The percentage of eggs containing bacteria was as follows: 8.7 per cent of eggs with sound shells, 18.6 per cent of eggs with cracked shells, and 30.7 per cent of eggs with leaking shells. (Table III, Part I.) The percentage of eggs containing *B. coli* was found also to be dependent upon the condition of the shell (Table III, Part III).

¹ Kossowicz, Alexander. Die Zersetzung und Haltbarmachung der Eier, pp. 42-54. Wiesbaden, 1913.

² Bacteriological Studies on Eggs. Kansas State Agr. Col. Exp. Sta., Bul. 180. 1911.

³ U. S. Dept. Agr. Bul. 51, pp. 3, 4. 1914.

⁴ Centbl. Bakt., [etc.] 2 Abt., 39 (1914), 611-624.

The number of bacteria in the eggs which contained organisms varied widely for the three groups, as can be seen from Part II of Table III. This is what would be expected, because after bacteria have once entered an egg the number present depends upon conditions favoring growth, such as warm temperatures.

These data substantiate the popular belief that organisms may penetrate eggs with sound shells if unfavorable conditions, such as filth, moisture, and high temperatures, are incurred during marketing, but not to such an extent as they penetrate cracked shells. The chance of contamination is greater in the case of leaking eggs, owing to exposure of the contents.

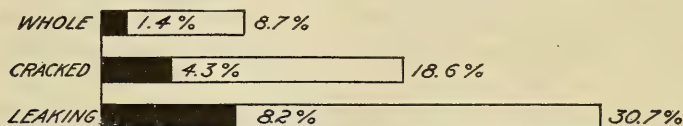


FIG. 2.—Relation of bacteria to soundness of shell. Total bar = per cent containing bacteria. Black portion of bar = per cent containing organisms fermenting lactose bile.

TABLE III.—*Relation of bacteria in eggs to soundness of shell.*

I. EGGS CONTAINING BACTERIA.

Description of shell.	Number examined.	Number positive.	Per cent positive.
Whole.....	1,167	101	8.7
Cracked.....	784	146	18.6
Leaking.....	101	31	30.7
Total.....	2,052	278	13.5

¹ 29 blind checks, 2 of which (6.9 per cent) contained bacteria, are included in this number.

II. VARIATION IN BACTERIAL CONTENT OF EGGS CONTAINING BACTERIA.

Description of shell.	Number of bacteria per cc.												Total number of eggs.
	101 to 1,000.		1,001 to 10,000.		10,001 to 50,000.		50,001 to 100,000.		100,001 to 500,000.		Over 500,000.		
	Number eggs.	Per cent.	Number eggs.	Per cent.	Number eggs.	Per cent.	Number eggs.	Per cent.	Number eggs.	Per cent.	Number eggs.	Per cent.	
Whole.....	33	32.7	15	14.8	8	7.9	9	8.9	7	6.9	29	28.7	101
Cracked.....	35	24.0	24	16.3	25	17.1	10	6.8	20	13.7	32	21.9	146
Leaking.....	8	25.8	6	19.4	3	9.7	1	3.2	5	16.1	8	25.8	31
Total.....	76	27.4	45	16.2	36	12.9	20	7.2	32	11.5	69	24.8	278

III. EGGS CONTAINING ORGANISMS FERMENTING LACTOSE BILE.

Description of shell.	Number examined.	Number positive.	Per cent positive.
Whole.....	1,132	6	1.4
Cracked.....	751	32	4.3
Leaking.....	97	8	8.2
Total.....	1,980	56	2.8

CLEANLINESS AND SOUNDNESS OF SHELL.

As would be expected, the percentage of eggs containing bacteria is less in eggs with clean shells than in those with dirty shells, and the percentage of eggs with bacteria becomes greater as the damage to the shell increases. The percentage of the eggs which contained bacteria, as shown by Table IV, Part I, and by figure 3, was as follows: 7.5 per cent for clean whole eggs, 10.8 per cent for dirty whole eggs, 17.2 per cent for clean cracked eggs, 23.2 per cent for dirty cracked eggs, 28.2 per cent for clean leakers, and 39.1 per cent for dirty leaking eggs.

The number of eggs harboring *B. coli* was also affected by the condition of the shell. Inasmuch as the number of leaking eggs examined for *B. coli* was too few to warrant conclusions, the few results obtained from them are grouped with the cracked eggs. Table IV, Part III, shows that 0.3 per cent (no more than the probable chance of experimental error) of the clean whole eggs, 3.4 per cent of the dirty

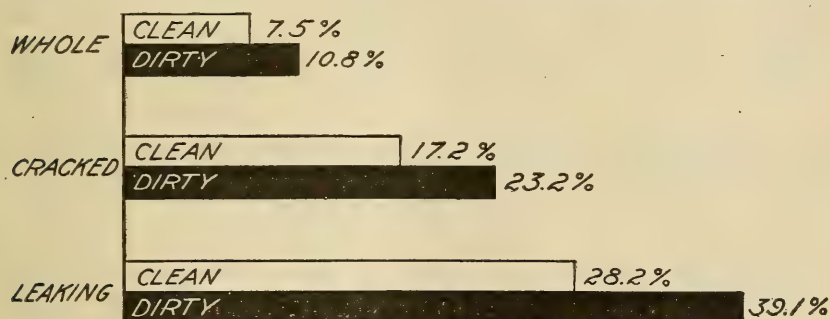


FIG. 3.—Relation of bacteria to soundness and cleanliness of shell.

whole eggs, 3.7 per cent of the clean, cracked, and leaking eggs, and 7.8 per cent of the dirty, cracked, and leaking eggs, contained these gas-producing bacteria.

It can be seen from Table IV that the percentage of eggs containing *B. coli* is practically the same for the clean, cracked, and leaking eggs as for the dirty eggs with whole shells. This is explained by the large number of these organisms in the hen feces, the most prevalent form of filth on hen's eggs.

The marked contrast between the bacterial content of eggs with clean sound shells and those with cracked or dirty shells, or both, emphasizes the care which farmers and carriers should exercise to prevent the soiling and damaging of shells.

The methods followed at present by the more progressive and careful egg handlers show that considerable care is being taken in the handling of eggs. When eggs are being prepared for cold storage, packers aim to remove by inspection and by clicking all cracked and

leaking eggs, because it has been observed that such eggs become moldy or otherwise deteriorate much more quickly than eggs with sound shells. For the same reason dirty eggs are not held in storage in very large quantities, nor for a very long period, although the deterioration of such eggs is not so rapid as is the case with cracked and leaking eggs. The observations of practical egg handlers, as well as laboratory results, show clearly the necessity for breaking dirty and cracked eggs as promptly as possible and preserving them in a frozen or dried form.

TABLE IV.—*Relation of bacteria in eggs to cleanliness and soundness of shell.*

I. EGGS CONTAINING BACTERIA.

Soundness of shell.	Cleanliness of shell.	Number examined.	Number positive.	Per cent positive.
Whole.....	Clean.....	760	57	7.5
Do.....	Dirty.....	407	44	10.8
Cracked.....	Clean.....	599	103	17.2
Do.....	Dirty.....	185	43	23.2
Leaking.....	Clean.....	78	22	28.2
Do.....	Dirty.....	23	9	39.1
Total.....		2,052	278	13.5

II. VARIATION IN BACTERIAL COUNT OF EGGS CONTAINING BACTERIA.

Description of shell.	Number of bacteria per cc.												Total number of eggs.
	101 to 1,000.		1,001 to 10,000.		10,001 to 50,000.		50,001 to 100,000.		100,001 to 500,000.		Over 500,000.		
	Number of eggs.	Per cent.	Number of eggs.	Per cent.	Number of eggs.	Per cent.	Number of eggs.	Per cent.	Number of eggs.	Per cent.	Number of eggs.	Per cent.	
Whole and clean.....	22	38.8	10	17.5	3	5.2	3	5.2	4	7.0	15	26.3	57
Whole and dirty.....	11	25.0	5	11.4	5	11.4	6	13.6	3	6.8	14	31.8	44
Cracked and clean.....	24	23.3	21	20.4	19	18.4	4	3.8	13	12.6	22	21.4	103
Cracked and dirty...	11	25.6	3	6.9	6	13.9	6	13.9	7	16.3	10	23.3	43
Leaking and clean...	6	27.3	5	22.7	2	9.1	1	4.5	3	13.6	5	22.7	22
Leaking and dirty...	2	22.2	1	11.1	1	11.1	-----	-----	2	22.3	3	33.3	9
Total.....	76	-----	45	-----	36	-----	20	-----	32	-----	69	-----	278

III. EGGS CONTAINING ORGANISMS FERMENTING LACTOSE BILE.

Soundness of shell.	Cleanliness of shell.	Number examined.	Number positive.	Per cent positive.
Whole.....	Clean.....	727	2	0.3
Do.....	Dirty.....	405	14	3.4
Cracked and leaking.....	Clean.....	645	24	3.7
Do.....	Dirty.....	203	16	7.8
Total.....		1,980	56	2.8

RELATION BETWEEN THE NUMBER OF BACTERIA AND THE PHYSICAL CONDITION OF THE EGG CONTENTS.**CONDITION OF YOLK.**

The physical condition of an egg indicates to a large extent its state of preservation. The white of a strictly fresh egg is stiff and the yolk stands up firmly, as can be seen very clearly from Plate I.¹ As the egg ages, the white becomes thinner, the yolk flatter, and the vitelline membrane weaker. When a stale egg is opened, the vitelline membrane frequently is ruptured and the contents of the yolk flows into and through the white, as illustrated in Plate III.² This type of egg is commonly called a "weak egg" or a "soft egg," and occurs most frequently in summer weather. Fertile eggs showing advanced hatch spots almost invariably contain weak yolks.

Eggs produced in the spring of the year generally have a firm consistency; that is, both white and yolk have the viscosity of the fresh egg. Occasionally it happens that a portion of the contents of the yolk has seeped through the vitelline membrane into the white in sufficient amount to give it a yellowish tinge. (See Plate II.) Although this condition prevails before the egg is opened, it is rarely detected by candling.

Because of their physical condition neither "soft eggs" nor eggs with incipient seeping yolks can be separated satisfactorily into white and yolk. These eggs appear to have whole yolks before the candle. If, on breaking, their odor is normal and the white not green, they may be considered suitable for baking and cooking. When the seepage of the yolk is so advanced that it extends entirely through the white, the egg should be discarded. Such an egg has the appearance of a mixed rot before the candle.³

Further deterioration in the shell of a "weak egg" or "soft egg" results in the final rupture of the vitelline membrane and a partial mixing of white and yolk. This egg, which is one type of a mixed rot, is illustrated in Plate IV. The physical mixing of the white and yolk progresses until the egg becomes what is known as an addled egg or a white rot. Frequently, eggs containing blood rings or adherent yolks pass through the different stages of deterioration until they become addled eggs.

It was found that the percentage of eggs with bacteria increased with the physical breaking down of the yolk, as shown by Table V. The percentage of eggs containing bacteria was as follows: 10.6 for eggs with whole yolks, 22.7 for soft eggs, and 43.5 for eggs with partially addled contents or with yolks adherent to the shell. The results of the examination of eggs with partially or entirely

¹ Reprint from U. S. Dept. Agr. Bul. 51, pl. I, and U. S. Dept. Agr. Bul. 224, pl. XVII.

² Reprint from U. S. Dept. Agr. Bul. 224, pl. XIV.

³ U. S. Dept. Agr. Bul. 224, pl. XVI.

deteriorated yolks harmonize with those obtained in previous investigations.¹

These findings also show that a very large percentage of "soft eggs" consisted of sterile eggs. Consequently, the first stages of deterioration in the yolks of such eggs in most instances can not be ascribed to bacteria.

Deterioration in eggs that is not due to the presence of bacteria may be the result either of the action of native enzymes² or of osmosis³ of water from the white to the yolk, thereby causing the vitelline membrane to stretch and become weakened. It was the aim of the candlers at the commission houses to exclude eggs with adherent yolks or addled contents, but through error in candling a few of such eggs were present in the samples.

Part III of Table V shows that a larger proportion of the eggs with broken yolks contained bacteria than did those with whole yolks.

TABLE V.—*Relation of bacteria in eggs to condition of yolk.*

I. EGGS CONTAINING BACTERIA.

Description of yolk.	Number examined.	Number positive.	Per cent positive.
Whole.....	1,588	168	10.6
Broken.....	441	100	22.7
Adherent or addled.....	23	10	43.5
Total.....	2,052	278	13.5

II. VARIATION IN BACTERIAL CONTENT OF EGGS CONTAINING BACTERIA.

Description of yolk.	Number of bacteria per cc.												Total number of eggs.
	101 to 1,000.		1,001 to 10,000.		10,001 to 50,000.		50,001 to 100,000.		100,001 to 500,000.		Over 500,000.		
	Number of eggs.	Per cent.	Number of eggs.	Per cent.	Number of eggs.	Per cent.	Number of eggs.	Per cent.	Number of eggs.	Per cent.	Number of eggs.	Per cent.	
Whole.....	54	32.1	28	16.7	20	11.9	11	6.5	19	11.3	36	21.4	168
Broken.....	21	21.0	15	15.0	16	16.0	8	8.0	12	12.0	28	28.0	100
Adherent or addled.....	1	10.0	2	20.0	.....	.....	1	10.0	1	10.0	5	50.0	10
Total.....	76	.....	45	.....	36	.....	20	.....	32	.....	69	.....	278

III. EGGS CONTAINING ORGANISMS FERMENTING LACTOSE BILE.

Description of yolk.	Number examined.	Number positive.	Per cent positive.
Whole.....	1,527	30	2.0
Broken.....	431	21	4.9
Adherent or addled.....	22	5	22.8
Total.....	1,980	56	2.8

¹ U. S. Dept. Agr. Bul. 51, pp. 29, 30, 53, 54.

² U. S. Dept. Agr., Bureau of Chemistry Cir., 104, pp. 4, 5.

³ U. S. Dept. Agr., Bureau of Chemistry Cir., 83, p. 3.

POSITION OF YOLK.

When viewed before the candle the yolk of a perfectly fresh egg is found to be located slightly above the meridian and is symmetrical with the long axis of the egg. It is indistinct in outline and moves very sluggishly as the egg is turned. As the egg ages the yolk apparently becomes more opaque and may settle against the lowest part of the shell.

Of all the eggs studied 1,795, or 87.5 per cent, were eggs with free yolks; 248, or 12.1 per cent, eggs with yolks settled close to the shell, but not adhering; and 9, or 0.4 per cent, eggs in which the yolks were either addled or adherent to the shell. Fewer eggs with adherent yolks or addled contents are listed in Table VI, which gives the results of examination of eggs graded by the candling method, than are listed in Table V, where the eggs were graded out of the shell. The reason for this is that eggs with slightly adherent yolks are often difficult to detect by candling, especially if the shell is brown.

These results confirm earlier studies ¹ of similar eggs, in that they show that a settled yolk is not in itself an indication that the egg contains bacteria.

TABLE VI.—*Relation of bacteria in eggs to position of yolk.*

I. EGGS CONTAINING BACTERIA.

Position of yolk.	Number examined.	Number positive.	Per cent positive.
Free moving.....	1,795	241	13.4
Settled.....	248	32	12.9
Addled or adherent.....	9	5	55.5
Total.....	2,052	278	13.5

II. VARIATION IN BACTERIAL CONTENT OF EGGS CONTAINING BACTERIA.

Position of yolk.	Number of bacteria per cc.												Total number of eggs.
	101 to 1,000.		1,001 to 10,000.		10,001 to 50,000.		50,001 to 100,000.		100,001 to 500,000.		Over 500,000.		
	Number of eggs.	Per cent.	Number of eggs.	Per cent.	Number of eggs.	Per cent.	Number of eggs.	Per cent.	Number of eggs.	Per cent.	Number of eggs.	Per cent.	
Free moving.....	65	27.0	44	18.3	31	12.9	19	7.8	29	12.0	53	22.0	241
Settled.....	10	31.2	.....	.....	5	15.6	1	3.1	3	9.4	13	40.6	32
Addled or adherent..	1	20.0	1	20.0	.....	.....	.....	.....	.....	.....	3	60.0	5
Total.....	76	.....	45	.....	36	.....	20	.....	32	.....	69	.....	278

¹ U. S. Dept. Agr. Bul. 51, pp. 12, 30, 31.

TABLE VI.—*Relation of bacteria in eggs to position of yolk*—Continued.

III. EGGS CONTAINING ORGANISMS FERMENTING LACTOSE BILE.

Position of yolk.	Number examined.	Number positive.	Per cent positive.
Free moving.....	1,735	48	2.76
Settled.....	236	7	2.97
Addled or adherent.....	9	1	11.11
Total.....	1,980	56	2.7

DESCRIPTIONS AND BACTERIAL COUNTS OF EGGS GRADED OUT OF THE SHELL.

The fitness for food purposes of eggs sold in the shell is determined in the industry principally by candling. In addition to this examination, the progressive concerns which are preparing frozen and desiccated eggs grade each egg very carefully out of the shell according to its odor and appearance. Practically all of the cooperating houses used clear, uncolored glass cups in examining the eggs to facilitate grading, as the physical condition of an egg is seen more easily in a transparent than in an opaque container. Many eggs with light green whites are not detected in a metal cup because the container masks the color.

The system of grading worked out in the cooperating plants was used for the grading of the eggs when removed from the shell. An egg in which the yolk was whole, the albumen clear, and the odor normal was graded as good. If the yolk appeared whole before the candle but broke when dropped into the cup and the odor was good, the egg was graded as fit for food purposes. Any egg in which the yolk had so deteriorated that it was materially mixed with the white was discarded, even though there was no odor, as were also all addled eggs, the advanced stage of this type of egg. Eggs with heavily mottled yolks were graded as bad. (See Plate II.) All eggs in which the yolk clung to the shell, even to a slight degree, all eggs with green whites, and eggs containing diffuse blood or embryos showing blood rings were rejected. Eggs with an unpleasant odor, for example, musty eggs, sour eggs, and very strong eggs—eggs in which the natural odor of the egg is increased—were classed as bad. The descriptions and bacterial findings in the case of a typical lot of individual eggs are given in Table VII.

Of the eggs in the experimental samples which had been passed by the candler as edible, 171, or 8.3 per cent; were classed as bad when graded out of the shell by appearance or odor. Had these inedible eggs been sold in the shell their condition would not have been seen until they were broken by the consumer. They would be eliminated by the trained breaker from frozen products.

TABLE VII.—*Descriptions and bacterial findings of a representative lot of individual eggs.*

[Sample No. 41149.]

No.	Description of shell.			Condition before the candle.			Condition out of the shell.		Number of organisms per cc on nutrient agar.	<i>B. coli</i> present in 1 cc of egg.
	Condi- tion.	Color.	Degree of cleanli- ness.	Shrinkage.	White.	Yolk.	Yolk.	Odor.		
1	Whole.	White.	Badly stained.	Marked.	Thick.	Whole.	Whole.	Good.	0	0
2	Cracked.	do.	Stained with egg.	Slight.	do.	do.	Broken.	do.	0	0
3	Whole.	do.	Clean.	do.	do.	Whole, tendency to settle.	do.	do.	0	0
4	Cracked.	do.	do.	Marked.	Thin.	Whole.	do.	do.	0	0
5	do.	do.	do.	Air cell invisible before can- dle.	Thick.	do.	Whole.	do.	0	0
6	do.	do.	do.	Marked.	Thin.	do.	do.	do.	0	0
7	Whole.	do.	do.	Slight.	Thick.	do.	do.	do.	0	0
8	Cracked.	Brown.	do.	Marked.	do.	do.	Whole, enlarged hatch spot.	do.	0	0
9	do.	White.	do.	do.	do.	do.	Whole.	Strong.	280,000	+
10	Leaking.	Brown.	do.	Very marked.	do.	do.	do.	Good.	0	0
11	Whole.	White.	do.	Slight.	Thin.	do.	do.	do.	0	0
12	do.	do.	Stained with egg.	do.	do.	do.	do.	Strong.	0	0
13	do.	Brown.	Clean.	do.	Thick.	do.	do.	Good.	0	0
14	Leaking.	do.	Very dirty.	Very marked.	do.	do.	do.	do.	140,000	0
15	do.	do.	Clean.	do.	Thin.	do.	do.	do.	610	0
16	Whole.	do.	do.	Marked.	do.	Whole, floats near shell.	Broken.	Strong.	0	0
17	Leaking.	do.	do.	Very marked.	do.	Whole.	Whole.	do.	0	0
18	Cracked.	do.	do.	do.	do.	do.	do.	do.	0	0
19	do.	do.	do.	Slight.	do.	do.	do.	do.	0	0
20	do.	do.	do.	do.	do.	Whole, settled.	do.	do.	0	0
21	do.	White.	do.	Marked.	do.	do.	do.	do.	0	0
22	Whole.	Brown.	Stained.	Slight.	do.	do.	Broken.	do.	0	0
23	Leaking.	do.	Clean.	Marked.	do.	do.	Whole.	do.	0	0
24	Whole.	do.	Stained.	Slight.	do.	do.	do.	do.	0	0
25	do.	White.	do.	do.	do.	do.	do.	do.	0	0
26	do.	Brown.	Clean.	Marked.	do.	do.	do.	do.	0	0
27	Cracked.	White.	do.	Very marked.	do.	do.	do.	do.	60	0
28	Leaking.	Brown.	Smearred with egg.	Slight.	do.	do.	do.	do.	290	0
29	do.	White.	Clean.	do.	do.	do.	do.	do.	0	0
30	Cracked.	Brown.	do.	Slight.	do.	do.	do.	do.	0	0
31	do.	do.	Dirty.	Marked.	do.	do.	do.	Strong.	0	0
32	Whole.	do.	do.	do.	do.	do.	do.	Good.	0	0
33	Cracked.	White.	do.	Very marked.	do.	do.	do.	do.	0	0
34	do.	do.	Clean.	do.	do.	do.	do.	do.	6,400	0

TABLE VII.—*Descriptions and bacterial findings of a representative lot of individual eggs—Continued.*

No.	Description of shell.		Condition before the candle.				Condition out of the shell.		Number of organisms present on 1 cc nutrient agar.	<i>B. coli</i> present in 1 cc of egg.
	Condition.	Color.	Degree of cleanliness.	Shrinkage.	White.	Yolk.	Yolk.	Odor.		
135	Cracked.	White.	Clean.	Very marked.	Light green.	Whole.	Broken.	Good.	(²)	+
136	do.	do.	do.	Marked.	White and yolk nearly mixed.	do.	White and yolk partially mixed.	do.	(²)	+
37	do.	do.	do.	do.	Thin.	Whole.	Whole.	do.	0	0
38	do.	do.	do.	do.	do.	do.	do.	do.	0	0
139	do.	do.	Stained.	Very marked.	do.	do.	Small blood ring.	do.	0	0
40	Leaking.	do.	Slightly dirty.	do.	do.	do.	Broken.	do.	0	0
41	do.	do.	Stained.	do.	do.	do.	Whole.	Strong.	0	0
42	Cracked.	do.	Clean.	Marked.	do.	do.	do.	Good.	0	0
43	Leaking.	do.	do.	do.	do.	do.	do.	do.	130,000	0
44	Cracked.	do.	do.	Slight.	do.	do.	do.	do.	500	0
45	do.	do.	do.	do.	do.	do.	do.	do.	0	0
46	do.	do.	do.	do.	do.	do.	Broken.	do.	0	0
47	do.	do.	Stained.	Marked.	do.	do.	Whole.	do.	0	0
48	do.	do.	Clean.	Slight.	do.	Whole, settled.	do.	Slight, abnormal.	(²)	+
49	do.	do.	do.	do.	do.	Whole.	Broken.	do.	0	0
50	do.	do.	do.	Marked.	do.	do.	Whole.	Strong.	0	0
51	Whole.	do.	Stained.	do.	do.	do.	do.	Good.	0	0
52	do.	do.	Clean.	do.	do.	do.	do.	do.	0	0
53	Cracked.	do.	do.	Slight.	do.	do.	do.	do.	0	0
54	do.	do.	do.	Marked.	do.	do.	do.	do.	0	0
55	Leaking.	do.	do.	Slight.	do.	do.	do.	do.	0	0
56	Cracked.	do.	Stained.	Marked.	do.	do.	do.	do.	(²)	0
57	do.	do.	Clean.	Slight.	do.	do.	Broken.	Strong.	0	+
58	do.	do.	do.	do.	do.	do.	Whole.	Good.	0	0
59	do.	do.	Stained.	Very marked.	do.	do.	do.	Strong.	0	0
60	Whole.	do.	Clean.	Marked.	do.	do.	do.	Good.	0	0
61	do.	Brown.	do.	Slight.	do.	do.	do.	do.	(²)	+
62	Cracked.	do.	do.	do.	do.	do.	do.	do.	0	0
63	Whole.	do.	do.	Marked.	do.	do.	do.	do.	(²)	0
64	Cracked.	White.	do.	Slight.	do.	do.	do.	do.	0	0
65	do.	do.	do.	do.	do.	do.	do.	do.	0	0
66	Whole.	do.	Stained.	Marked.	do.	do.	Broken.	Strong.	0	0
67	Cracked.	do.	Clean.	do.	do.	do.	do.	do.	0	0
68	Whole.	Brown.	do.	do.	do.	do.	Whole.	do.	0	0
69	Cracked.	White.	do.	Slight.	do.	do.	Broken.	Good.	0	0
70	do.	do.	Stained.	do.	do.	do.	Whole.	do.	4,100	+
			Clean.	do.	do.	do.	do.	do.	500	0

¹ Rejected as unfit for food purposes.² Innumerable in dilution of 1 to 1,000.

TABLE VIII.—*Bacterial findings in eggs graded out of the shell.*

I. EGGS CONTAINING BACTERIA.

	Grade.	Number examined.	Number positive.	Per cent positive.
Good.....		1,881	225	12.0
Bad.....		171	53	31.0
Total.....		2,052	278	13.5

II. EGGS CONTAINING ORGANISMS FERMENTING LACTOSE BILE.

Good.....	1,809	40	2.2
Bad.....	171	16	9.4
Total.....	1,980	56	2.8

TABLE IX.—*Eggs containing bacteria and graded out of the shell as good.*

Sample No.	Number of bacteria per cc.												Total number of eggs.
	101 to 1,000.		1,001 to 10,000.		10,001 to 50,000.		50,001 to 100,000.		100,001 to 500,000.		Over 500,000.		
	Number of eggs.	Per cent.	Number of eggs.	Per cent.	Number of eggs.	Per cent.	Number of eggs.	Per cent.	Number of eggs.	Per cent.	Number of eggs.	Per cent.	
41142.....													0
41143.....													0
41144.....			1	100.0									1
41145.....													0
41146.....	1	50.0	1	50.0									2
41147.....	1	100.0											1
41148.....													1
41149.....	5	35.7	2	14.3					3	21.4	4	100.0	14
41161.....													0
41164.....	1	50.0									1	50.0	2
41167.....											1	100.0	1
41169.....											3	100.0	3
41175.....	3	37.5	1	12.5	2	25.0					2	25.0	8
41178.....	1	50.0									1	50.0	2
41180.....	7	70.0			1	10.0					2	20.0	10
41182.....	3	50.0	1	16.7	1	16.7	1	16.6					6
41185.....	2	66.7									1	33.3	3
41189.....	1	33.3									2	66.7	3
41192.....	4	7.3	11	20.0	14	25.4	8	14.6	13	23.6	5	9.1	55
41316.....	3	60.0	1	20.0							1	20.0	5
41435.....	1	20.0	1	20.0	1	20.0					2	40.0	5
41438.....	1	20.0							1	20.0	3	60.0	5
41505.....	1	20.0			1	20.0	1	20.0			2	40.0	5
41506.....	1	16.7	1	16.7	2	33.3	1	16.7			1	16.6	6
41509.....	2	50.0									2	50.0	4
41551.....	7	77.8	2	22.2									9
41594.....	4	57.1					1	14.3			2	28.6	7
41598.....	12	80.0	1	6.7	1	6.7			1	6.6			15
41645.....	11	21.2	19	36.5	10	19.2	6	11.5	4	7.7	2	3.9	52
Total.....	72	32.0	42	18.6	33	14.7	18	8.0	22	9.8	38	16.9	225

A bacteriological examination of the eggs graded out of the shell as edible showed that 12 per cent contained bacteria and 2.2 per cent *B. coli*. (See Table VIII.) The bacterial content of the great majority of the individual eggs included in the edible group, however, was low, as may be seen from Table IX. The variation in the counts of the eggs containing bacteria was as follows: 65.3 per cent were under 50,000; 16.9 per cent were over 500,000; and the remainder were between these two limits.

Of the total number of eggs which had been graded by the candle as edible, 69, or 3.4 per cent, were found to contain over 500,000 organisms per gram. (See Table II.) Nearly half, or 44.9 per cent, of these eggs, as computed from Tables II, IX, and XIII, were detected when graded out of the shell and eliminated from the composite samples. The remaining 55.1 per cent did not show either by appearance or odor that they were infected, and would have been used by egg breakers. A record of the appearance of each of these infected eggs is given in Table X.

EFFECT OF CONTAMINATED EGGS UPON COMPOSITE PRODUCTS.

The bacterial contents of the composite samples prepared from the eggs graded as good were in proportion to the degree of contamination of the eggs constituting them. The percentage of eggs containing bacteria in liquid mixtures composed of 69 to 72 eggs varied from 0 to 21.1 per cent, except in two samples which showed 73.2 per cent and 100 per cent. These samples represent lots 41192 and 41645 already discussed as exceptions on pages 4 and 5. The bacterial counts of the composite samples varied from 0, where all eggs were sterile, to 14,000,000, where the percentage of eggs with bacteria reached 81.3 per cent. (See Table XI.)

The percentage of eggs containing *B. coli* varied from 0 to 41.8 per cent in the different composite samples. The number of *B. coli* contributed to the composite product by the individual eggs varied from 0 to 500,000 per gram.

The percentage of ammoniacal nitrogen in the 29 lots of eggs was practically the same as that found in the commercial samples of frozen eggs. (Tables XI and XII.)

A survey of the bacterial counts given in Table XI shows decided similarity to those obtained in samples from the plants which have been cooperating in this investigation (see Table XII), and which have put into practical application the information obtained in the laboratory. Apparently certain eggs the condition of which can not now be detected by the senses are carriers of bacteria. However, it is very seldom that such eggs cause in the composite sample a bacterial count of more than a few millions. There is an agreement, also, between the number of *B. coli* in the commercial samples of well-handled eggs and the number found in the samples reported in this investigation.

In the cooperating plants the eggs were handled in refrigerated rooms, broken according to a routine involving strict cleanliness, and graded in accordance with the best available information. Faulty grading of the breaking stock either during candling or breaking may result in serious bacterial contamination of the product,

TABLE X.—Description of individual eggs with bacterial counts of over 500,000 per gram.
[Graded out of the shell as good.]

Sam- ple No.	Egg No.	Description of shell.		Condition before the candle.			Condition out of the shell.		
		Condition.	Color.	Degree of cleanliness.	Shrinkage.	Yolk.	White.	Yolk.	Odor.
41148	43	Whole.....	Dark brown...	Clean.....	Marked.....	Tendency to settle.	Thin.....	Whole, with dark areas	Good.
41149	47	Cracked.....	White.....	Stained.....	Slight.....	Settled.....	do.....	Whole.....	Slightly abnormal.
41149	56	do.....	do.....	do.....	do.....	Normal.....	do.....	Broken.....	Strong.
41149	60	Whole.....	do.....	Clean.....	Marked.....	do.....	do.....	Whole.....	Good.
41149	62	do.....	Brown.....	do.....	do.....	do.....	do.....	do.....	Do.
41164	61	Leaking.....	White.....	do.....	do.....	do.....	do.....	do.....	Do.
41167	44	Whole.....	Brown.....	do.....	do.....	do.....	do.....	do.....	Do.
41169	6	do.....	White.....	Dirty.....	do.....	Floats near shell.	Thin, turbid.	Whole, with dark areas	Strong.
41169	67	do.....	Brown.....	Stained.....	do.....	Medium position.	Thin.....	Whole.....	Do.
41169	71	do.....	White.....	Clean.....	do.....	Normal.....	do.....	Whole, with dark areas	Do.
41175	28	do.....	Brown.....	Dirty.....	Slight.....	Medium position.	do.....	Broken.....	Do.
41175	43	do.....	White.....	do.....	Marked.....	Normal.....	do.....	do.....	Good.
41178	50	Cracked.....	do.....	Clean.....	do.....	Below meridian line.	do.....	Whole, with dark areas	Slightly abnormal.
41180	9	do.....	do.....	Dirty.....	do.....	Medium position.	do.....	Flat.....	Strong.
41180	32	Leaking.....	do.....	Clean.....	do.....	Below meridian line.	do.....	Normal.....	Slightly abnormal.
41185	45	Whole.....	do.....	Washed.....	do.....	Weak.....	do.....	Badly broken	Do.
41189	3	Porous.....	Brown.....	Clean.....	do.....	Medium position.	do.....	Normal.....	Do.
41189	52	Cracked.....	do.....	do.....	Slight.....	Settled.....	do.....	do.....	Do.
41192	2	do.....	do.....	do.....	Marked.....	Normal.....	do.....	Broken.....	Do.
41192	4	Leaking.....	White.....	do.....	do.....	do.....	do.....	Normal.....	Do.
41192	17	Whole.....	do.....	Dirty.....	Slight.....	Below meridian line.	do.....	do.....	Do.
41192	62	Cracked.....	do.....	do.....	do.....	Settled.....	do.....	Broken.....	Do.
41192	67	do.....	Brown.....	do.....	do.....	Normal.....	do.....	do.....	Do.
41316	55	Leaking.....	do.....	Clean.....	do.....	do.....	do.....	do.....	Do.
41435	23	Cracked.....	White.....	do.....	Marked.....	Settled.....	do.....	Broken and wrinkled	Doubtful sour.
41435	35	do.....	do.....	Stained.....	Slight.....	Below meridian line.	do.....	Broken.....	Good.
41438	4	Light leaker	do.....	Clean.....	Marked.....	Normal.....	do.....	Normal.....	Do.
41438	18	do.....	do.....	do.....	do.....	Medium position.	do.....	do.....	Do.
41438	53	Cracked.....	do.....	do.....	do.....	Settled.....	do.....	do.....	Do.
41505	38	Whole.....	Brown.....	Stained.....	do.....	Medium position.	do.....	do.....	Stale.
41505	50	Cracked.....	White.....	Clean.....	do.....	do.....	do.....	do.....	Good.
41506	64	do.....	do.....	do.....	do.....	do.....	do.....	do.....	Do.
41509	47	Cracked.....	Brown.....	do.....	do.....	Below meridian line.	Deep opalescent.	do.....	Do.
41509	52	do.....	do.....	do.....	do.....	do.....	Thin.....	do.....	Do.
41594	1	Whole.....	do.....	do.....	Slight.....	Normal.....	do.....	do.....	Do.
41594	56	Blind check	White.....	do.....	Marked.....	Medium position.	do.....	do.....	I.e.
41645	24	Cracked.....	Brown.....	Stained.....	do.....	do.....	do.....	do.....	Strong.
41645	33	do.....	do.....	do.....	Slight.....	Invisible.	do.....	do.....	Doubtful sour.
					do.....	Normal.....	Turbid.....	do.....	Good.

¹ As no air-cell was visible the degree of shrinkage could not be determined by candling.

Contamination of the product during manufacture was minimized. The rooms in which the eggs were broken were lined with concrete, the walls were enameled in white, and all the windows were kept closed so that dust could not enter. As an additional precaution the windows were at least triple paned for insulation. All utensils were frequently washed and sterilized and clean apparatus was substituted during breaking whenever any utensil was contaminated by a bad egg. The two principal extraneous sources of bacteria which could not be controlled entirely were the shells of the eggs and the fingers of the breaker. By washing the hands after breaking a bad egg, and by frequently drying the fingers on tissue paper, the number of bacteria derived from these sources was greatly minimized.

The presence of bacteria in commercial frozen and desiccated eggs is due to two causes, namely, contamination during preparation and the quality of the raw material used. In Department Bulletin 224 it was shown that improperly cleaned utensils and faulty manipulation of the egg during breaking contributed many bacteria to the product during the process of preparation. In Department Bulletins 51 and 224, and in the present paper, it has been shown that the bacterial count of the finished product decreases in proportion to the quality of the eggs used.

TABLE XI.—*Laboratory findings in composite samples of individual eggs graded as good.*

Sample No.	Number of eggs in sample.	Number of eggs in sample contributing bacteria. ¹	Bacteria per gram on plain agar incubated at—		Gas-producing bacteria per gram in lactose bile.	Eggs containing gas-producing bacteria.	Ammoniacal nitrogen.		Moisture.
			20° C.	37° C.			Wet basis.	Dry basis.	
							<i>P. ct.</i>	<i>P. ct.</i>	<i>P. ct.</i>
41142	69	0	Less than 100	Less than 100	Less than 100	0	0.0019		
41143	72	0	Less than 10	Less than 10	0	0	.0013	0.0048	72.87
41144	68	1	190	Less than 10	0	1	.0015	.0055	72.96
41145	67	0	650	550	100	0	.0024	.0087	72.45
41146	68	2	600	Less than 100	Less than 100	1	.0018	.0067	72.96
41147	39	1	Less than 100	Less than 100	0	0	.0015	.0057	73.21
41148	72	1	600,000	490,000	0	0	.0022		
41149	67	14	13,000,000	10,000,000	1,000	7	.0018	.0066	72.64
41161	66	0	130,000	98,000		0	.0018	.0074	75.59
41164	68	2	410	340	0	1			73.34
41167	64	1	55,000	37,000	0	0			
41169	65	3	7,500,000	8,100,000	10,000	1	.0011	.0040	72.34
41175	58	8	19,000	19,000	1,000	1	.0021	.0076	72.22
41178	65	2	65,000	58,000	0	1	.0018	.0065	72.34
41180	63	10	3,200,000	350,000	0	3	.0021	.0076	72.28
41182	59	6	1,200,000	13,000	0	0	.0024	.0089	73.11
41185	69	3	1,700	1,000	100	4	.0022		
41189	68	3	40,000	50,000	Less than 100		.0018	.0067	73.25
41192	55	55				23	.0020	.0076	73.69
41316	60	5	Less than 1,000	Less than 1,000	10	1	.0015	.0055	72.70
41435	62	5	52,000	53,000	10,000	3	.0022	.0081	72.82
41438	60	5	2,400,000	2,200,000	500,000	4	.0022	.0080	72.38
41505	65	5	410,000	430,000	0	2	.0021		
41506	69	6	3,500	1,000	1,000	2	.0017	.0063	73.17
41509	69	4	140,000	170,000	0	1	.0020	.0074	72.85
41551	70	9	1,100	1,100	0	0	.0014	.0052	73.13
41594	69	7	3,100,000	550	0	0			
41598	71	15	17,000	400	0	0	.0021	.0074	71.69
41645	64	52	14,000,000	10,000,000	0	0	.0015	.0054	72.05

¹ The bacterial counts of these eggs are given in Table IX.

Other conditions being equal, eggs with cracked and leaking shells give a product with a higher bacterial count than do eggs with shells that are sound, even though dirty. Frozen or dried eggs made from summer and fall breaking stock have fewer bacteria than similar products made from spring breaking stock. The breaking of eggs as near the source of production as possible results in the presence of fewer bacteria in products prepared during the warm portion of the season.

TABLE XII.—General summary of laboratory results on commercial samples of frozen egg taken in three houses during 1912.¹

I. BACTERIOLOGICAL RESULTS.

Description of sample.	Number of samples.	Percentage of samples with counts over 5,000,000 per gram.	Number of organisms per gram.		
			Average.	Minimum.	Maximum.
Liquid eggs:					
Whites.....	39	2.6	2 350,000	100	7,500,000
Yolks.....	54	5.56	3 530,000	200	7,500,000
Whole eggs.....	47	21.28	2,700,000	340,000	11,000,000
Mixed eggs from D house.....	46	-----	1,000,000	5,100	3,300,000
Mixed eggs from F house.....	12	8.33	1,700,000	470,000	6,800,000
Leaking eggs.....	53	5.88	1,300,000	500	6,000,000
Soft eggs.....	13	46.14	20,000,000	130,000	80,000,000

II. CHEMICAL RESULTS.

Description of sample.	Number of samples.	Percentage of ammoniacal nitrogen.						Percentage of moisture.		
		Wet basis.			Dry basis.			Average.	Minimum.	Maximum.
		Average.	Minimum.	Maximum.	Average.	Minimum.	Maximum.			
Whites.....	13	0.0004	0.0002	0.0006	0.0031	0.0016	0.0049	87.37	86.96	88.31
Yolks.....	23	.0032	.0024	.0045	.0076	.0054	.0103	57.88	53.64	64.06
Whole eggs.....	43	.0021	.0016	.0024	.0074	.0054	.0087	72.33	70.23	74.17
Mixed eggs from D house.....	34	.0020	.0014	.0025	.0067	.0046	.0082	68.88	68.33	71.43
Mixed eggs from F house.....	10	.0023	.0017	.0027	.0071	.0053	.0082	68.06	67.00	70.81
Leaking eggs.....	37	.0020	.0013	.0028	.0065	.0047	.0080	69.63	64.12	72.83
Soft eggs.....	11	.0023	.0018	.0031	.0080	.0066	.0098	71.24	67.04	72.99

¹ U. S. Dept. Agr. Bul. 224, p. 20.

² One sample with an exceptionally high count not included in this average.

³ Three samples with exceptionally high counts not included in this average.

EGGS REJECTED DURING GRADING.

EGGS WITH UNDESIRABLE ODOR.

The important part which the sense of smell plays in the grading of breaking stock is shown by the fact that 90 or 52.6 per cent of the rejected eggs, as computed from Table XIII, were eliminated because of an abnormal odor. One-half of the eggs discarded because of odor were musty, and the other half had bad odors of various kinds.

The eggs are classified in Table XIV according to odor. The first group consists of 16 eggs with a bad odor. The laboratory examina-

tions showed that 11 contained bacteria, and 7 of these eggs were heavily contaminated. It is probable that absorption from surrounding materials accounts for the abnormal odor in the other 4 eggs. Operators of cold-storage warehouses have found that eggs stored in the same room with fruits, such as oranges or lemons, absorb the odors of such fruits. When eggs are opened in the breaking plants many varieties of absorbed odors are encountered. Eggs with the odor of kerosene or moth balls are not uncommon. Both materials are used in hen houses to inhibit the development of vermin; one as a spray and the other as a nest egg.

Mold infection very frequently is associated with the presence of both bacteria and molds.¹ It is not unexpected, therefore, to find that fully two-thirds of the eggs with a moldy odor contained bacteria.

It has been found that sour eggs are very heavily contaminated with organisms of the *B. coli* group and that they often contain bacteria in numbers equal to those found in black rots.² Only 5 sour eggs were present in the 29 samples. In two instances the egg was graded as a "doubtful sour," as it was not always possible to determine conclusively the dividing line between a sour egg and one that was not sour. This accounts for the sterility of two of the eggs in which it was not certain that the odor was sour.

Considerable care is exercised in the cooperating plants in the grading of eggs with abnormal odors. All eggs, even if they appear sound, are smelled carefully, and if there is any doubt as to whether the odor is due to absorption or spoilage, the questionable egg is discarded.

The musty egg has a peculiarly characteristic odor and taste. In some cases its odor resembles that of old fillers and flats, in others that of certain kinds of weeds or of spoiling hay or chaff, and in still others the odor of sprouting potatoes. As its condition can not be seen by the candle, a musty egg must be detected by its odor out of the shell. Its odor can not always be expelled by cooking. The possible presence of such an egg in breaking stock and the unfortunate results which are likely to occur if it is present in cake or cookie dough made egg breakers realize that eggs must be graded out of the shell as well as by the candle.

Egg handlers frequently do not distinguish between moldy and musty eggs, although the two are distinctly different. The moldy egg is caused by the growth of molds in the egg substance and has an odor characteristic of damp cellars. The musty egg usually is normal in appearance, in fact it frequently resembles a perfectly fresh egg. Occasionally, however, a musty egg with a green white is encountered.

¹ U. S. Dept. Agr. Bul. 51, pp. 33-38, 46.

² U. S. Dept. Agr. Bul. 51, pp. 61-64.

A striking feature of the bacteriological study of musty eggs, excluding those with green whites, is their sterility. Of the 45 musty eggs examined, only three, as shown in Table XIII, contained bacteria. One had 350 organisms, and the other two had 200,000 and 150,000, respectively. The latter two eggs were from sample 41,192, which consisted entirely of eggs showing bacteria. The ammoniacal nitrogen found in musty eggs is not excessive.¹

Most of the musty eggs were from samples procured in the spring. Sample 41147, which contained a large number of musty eggs, was purchased from a grocery store located in one of the poorer sections of a large city. The eggs had clean brown shells and showed practically no shrinkage on candling. The shells, however, did not have the bloom characteristic of fresh eggs, but had rather the appearance of having been washed.

The most rational theory advanced by the trade regarding the cause of musty eggs is that it may be due to absorption from surrounding materials. If the musty odor is the result of such absorption, it is difficult to explain why it does not become weaker as the egg ages in the shell or in the frozen state; also why the odor in cake or confectionery does not always disappear in baking. Other types of odors do not remain with such persistence. The cause of musty eggs is still unknown.

SOFT EGGS.

Soft eggs represent a transition stage between edible and inedible eggs. If the yolk breaks or is found to be broken when the egg is opened, it is necessary to determine whether or not the egg is fit for food. An egg with simply a ruptured vitelline membrane is not rejected, but if other signs of deterioration, such as whitish streaks in the yolk or a muddy white, are present, it is not considered edible. (See Plate IV.) Sometimes it is found that the yolk of an egg appears very weak before the candle and, on breaking, its outline is practically lost because the yolk material has so quickly intermingled with the white. This type of egg, shown in Plate V, is called by the industry a "runny egg" and is discarded. The soft eggs with the whitish streaks in the yolk and the "runny eggs" very closely approximate the degree of physical deterioration found in mixed rots. Soft eggs sometimes have a sour odor, in which case they are heavily infected with bacteria.²

There were 447 soft eggs in the eggs under observation. Of these, 0.7 per cent were found to be sufficiently deteriorated to warrant their exclusion from food products. About 20 per cent of these rejected eggs showed infection.

¹ Unpublished results.

² U. S. Dept. Agr. Bul. 51, p. 61.

Soft eggs found when commercially separating eggs into white and yolk usually contain more bacteria and more ammoniacal nitrogen than do edible frozen whole eggs, as may be seen from Table XII, which summarizes the laboratory findings in commercial products.

The guiding principle to be followed in the grading of soft eggs is to reject every egg that has an odor or a yolk which shows any signs of deterioration other than the rupture of the vitelline membrane.

EGGS WITH GREEN WHITES.

Eggs with green whites constituted 10.5 per cent of the rejected eggs, and 66.6 per cent of these were seriously contaminated. These results are in agreement with those obtained in a more exhaustive study of this type of egg.¹ The six sterile eggs in the table were eggs in which the opalescence characteristic of fresh whites was confused with the "beginning green" of a green white egg.

WHITE AND MIXED ROTS.

White and mixed rots, or eggs with the yolk partially or entirely mixed with the white, are advanced forms of the soft egg. These eggs are generally recognizable before the candle. Only 19 passed the candler at the commission house into the experimental samples. They showed much more infection than did the soft eggs.²

TABLE XIII.—*Eggs rejected during grading.*

I. VARIATION IN BACTERIAL CONTENT.

Description of sample.	Number of bacteria per cc.														Total number of eggs.
	0 to 100		101 to 1,000		1,001 to 10,000		10,001 to 50,000		50,001 to 100,000		100,001 to 500,000		Over 500,000		
	Number of eggs.	Per cent.	Number of eggs.	Per cent.	Number of eggs.	Per cent.	Number of eggs.	Per cent.	Number of eggs.	Per cent.	Number of eggs.	Per cent.	Number of eggs.	Per cent.	
Eggs with abnormal odor, not musty.....	21	46.7	.....	.....	1	2.2	2	4.4	1	2.2	7	15.6	13	28.9	45
Musty eggs.....	42	93.3	1	2.2	.....	.....	.....	.....	.....	.....	2	4.5	3	.....	45
Soft eggs.....	26	81.3	2	6.3	.....	.....	1	3.1	.....	.....	.....	.....	3	9.4	32
Eggs with green whites.....	6	33.3	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	12	66.7	18
Mixed rots.....	6	54.5	.....	.....	2	18.2	.....	.....	1	9.1	1	9.1	1	9.1	11
White rots.....	6	75.0	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	2	25.0	8
Eggs with adherent yolks.....	2	66.7	1	33.3	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	3
Miscellaneous.....	9	100.0	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	9
Total.....	118	69.0	4	2.3	3	1.8	3	1.8	2	1.2	10	5.8	31	18.1	171

¹ U. S. Dept. Agr. Bul. 51, pp. 57-61.

² The results of other examinations of white and mixed rots are given in U. S. Dept. Agr. Bul. 51, pp. 29, 30, 53, 54.

TABLE XIII.—*Eggs rejected during grading—Continued.*

II. PERCENTAGE OF EGGS CONTAINING GAS-PRODUCING BACTERIA.

Description of sample.	Total number.	Number examined.	Number of eggs containing gas-producing bacteria.	Percentage of discards containing gas-producing bacteria.
Eggs with abnormal odor, not musty.....	45	42	6	14.3
Musty eggs.....	45	45	0	0
Soft eggs.....	32	32	0	0
Eggs with green whites.....	18	18	4	22.2
Mixed rots.....	11	10	2	20.0
White rots.....	8	8	2	25.0
Eggs with adherent yolks.....	3	3	0	0
Miscellaneous.....	9	9	0	0
Total.....	171	167	14	8.4

TABLE XIV.—*Summary of bacterial findings in eggs with abnormal odors.*

Kind of odor.	Number examined.	Number positive.	Per cent positive.	Number with over 500,000 bacteria.	Per cent with over 500,000 bacteria.
Unclassified bad.....	16	11	68.8	7	43.8
Moldy.....	6	4	66.7	3	50.0
Sour.....	5	3	60.0	2	40.0
Very strong.....	17	6	35.3	1	5.9
Musty.....	45	3	6.7	0	0
Coal tar.....	1	0	0	0	0

SUMMARY.

1. Despite careful candling a small number of breaking-stock eggs contain bacteria, particularly during the summer and fall months. The percentage of eggs containing *B. coli* is markedly lower than the total percentage of eggs harboring bacteria.

2. There is a progressive rise in the percentage of bacterial contamination through the following series: Clean whole eggs, dirty whole eggs, clean cracked eggs, dirty cracked eggs, clean leaking eggs, and dirty leaking eggs.

3. Eggs with weak yolks show a greater degree of bacterial contamination than do eggs with firm yolks.

4. A settled yolk is not *per se* an evidence of the presence of bacteria.

5. Eggs with adherent yolks and eggs with addled contents are not only abnormal in appearance, but, in many instances, are harborers of bacteria. They should not be included in food products.

6. Some eggs containing bacteria can not be recognized by their appearance or odor. A very large percentage of eggs containing bacteria, particularly those with high bacterial content, can, however, be recognized by the senses.

7. Despite careful grading out of the shell, the percentage of eggs containing bacteria in mixtures prepared for freezing or drying may average 12 per cent of the eggs used.

8. The number of bacteria per gram in composite products prepared for freezing or drying, due to unrecognized infected eggs, may vary from a few hundred to several million. Some but not all the *B. coli* in the composite mixtures prepared commercially are derived from the raw material.

9. A "weak egg" which has decomposed to such an extent that it has a muddy white or a whitish streak in the yolk should be discarded as unfit for food purposes, even though it may show no bacteria, as the absence of bacteria does not in itself signify that an egg is edible.

10. The musty egg does not usually contain bacteria, neither is it decomposed as judged by the appearance or the quantity of loosely bound nitrogen present. The cause of the musty egg is not known.

11. The production of frozen and dried egg products of good quality requires, first of all, good raw material, and, subsequently, care in grading the eggs both before the candle and out of the shell.

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EGG OUT OF THE SHELL, SHOWING YOLK SEEPING INTO THICK WHITE



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SOFT EGG OUT OF THE SHELL, SHOWING WHITE STREAKS IN YOLK



SOFT EGG OUT OF THE SHELL, SHOWING SPREADING YOLK



Washington, D. C.

PROFESSIONAL PAPER

August 23, 1916

LESSONS ON TOMATOES FOR RURAL SCHOOLS.¹By E. A. MILLER, *Specialist in Agricultural Education.*

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INTRODUCTION.

Importance.—The tomato has come to be looked upon as one of the most important truck crops. Its value as an article of food and the wide range in which it may be grown have made it both a commercial and a home garden crop of high rank.

Educational value.—The many phases involved in growing, harvesting, and marketing the crop give it value as an educational subject. This has been demonstrated in recent years by its utilization as a club project activity by young people. It is with a view of introducing into the schools in a definite way the study of this important plant that these lessons are outlined. Each lesson topic affords ample work for one or more recitation periods, and should be taught at the season of year indicated.

Practical exercises.—The principles set forth in each lesson should be emphasized and demonstrated by the pupils in the growing of tomatoes for profit under proper supervision. This is dealt with in more detail elsewhere.

References.—The publications referred to may be had from the U. S. Department of Agriculture, Washington, D. C., so long as available. Teachers and pupils should write to the State college of agriculture for publications on the subject. Let it be remembered that the classroom work can be made most effective only when a liberal use is made of supplementary literature. At the very beginning of the school year the teacher and pupils should secure all the available reference literature on the subject.

¹ Prepared under the direction of C. H. Lane, Chief Specialist in Agricultural Education.

NOTE.—This bulletin is of interest to teachers of southern rural schools.

Correlations.—In connection with each lesson topic some suggestions are made as to the utilization of the subject in vitalizing the other subjects in the school curriculum. These suggestions are not intended as a part of each lesson, but should be worked out in connection with the recitations in the other school subjects. It is hoped that the teachers will take advantage of these suggestions and elaborate them to meet local needs.

Note to the teacher.—To make the teaching of the lesson topics of this publication effective, three points must be kept in mind: (1) A monthly or seasonal sequence plan should be followed in the presentation of topics; (2) simple classroom exercises should be performed to illustrate and emphasize the principles contained in the lesson topics; (3) members of the class in agriculture should carry on home work or club work with tomatoes for profit. To have educational value this home work or club work should meet the following requirements:¹ (1) The work of growing tomatoes should be a part of the instruction in agriculture; (2) a definite plan should be followed in the growing of tomatoes; (3) the parents should agree to and approve the home work of the pupils; (4) the work should be carefully supervised by some competent person; and (5) detailed records of labor, methods, expenditures, yields, and incomes should be kept and reported upon in writing by the pupils.

LESSON ONE.

TOPIC: HISTORY AND IMPORTANCE.

MONTH: SEPTEMBER.

*Lesson outline.*²—History: The tomato is native to South America, having been grown by the original inhabitants. It belongs to the nightshade family, and for that reason was long thought to be poisonous. It is only in the last hundred years that it has come into general use. It is adapted to a wide range of climatic and soil conditions, but flourishes best in a mild climate and on a well-drained rich loam soil with a clay subsoil.

The tomato belongs to the same order of plants as do peppers and eggplants. While the real kinship of the tomato to these plants is not very close, botanically speaking, yet apparently they are quite closely related and might be classed as cousins. They require much the same cultivation and they are subject to some of the same pests. The same general instructions with reference to starting in hotbeds, hardening off in cold frames, transplanting and cultivating for tomatoes, are applicable to peppers and eggplants.

Importance: Great quantities of tomatoes are grown for home use and to be sold on the American markets. Thousands of acres are

¹ The term "home project," as used by school officers in certain sections of the United States, involves the same requirements as enumerated in this connection.

² The statements given in each lesson outline are based largely upon Farmers' Bulletins Nos. 220 and 642.

planted annually for canning, for soup, and for catsup. The home garden always contains a few tomato plants. The fruit is now so popular that hundreds of greenhouses are devoted to its culture to supply the trade during the winter or cooler seasons of the year. The census of 1910 shows the value of the tomato crop to be \$13,707,929.

Study questions: In what respects are tomato plants, eggplants, and pepper plants alike? In what respects unlike? In what respects are the fruits of these plants alike? Unlike? Compare the seeds of each. For what purposes are tomatoes grown in the community—market, canning factories, home use? In what forms do canning-club members dispose of their products?

References.—Farmers' Bul. 220.

Practical exercises.—Make a study of the types and varieties of tomatoes grown in the community. For this purpose use tables similar to the following:

Community survey of tomatoes, peppers, and eggplants.

	Variety.	Number of homes at which grown.	Special uses.	Early.	Late.
TOMATO.					
Commercial Group.....					
.....					
Preserving Group.....					
.....					
Currant Group.....					
.....					
PEPPERS.					
Pungent fruited.....					
.....					
Mild fruited.....					
.....					
EGGPLANTS.					
Black fruited.....					
.....					
Purple fruited.....					
.....					
White fruited.....					
.....					

Correlations.—Require the pupils to prepare tables similar to the foregoing to be used in making the community survey.

Arithmetic: Develop problems on the quantity and value of each of these crops.

History: It is thought that the tomato was carried from Peru to Europe. Locate Peru on the map and compare the climatic conditions of Peru with the Southern States; with the Mediterranean countries.

LESSON TWO.

TOPIC: VARIETIES.

MONTH: SEPTEMBER.

Lesson outline.—There has been developed a wide range of varietal forms (fig. 1) which may be grouped: (1) Commercial, of which

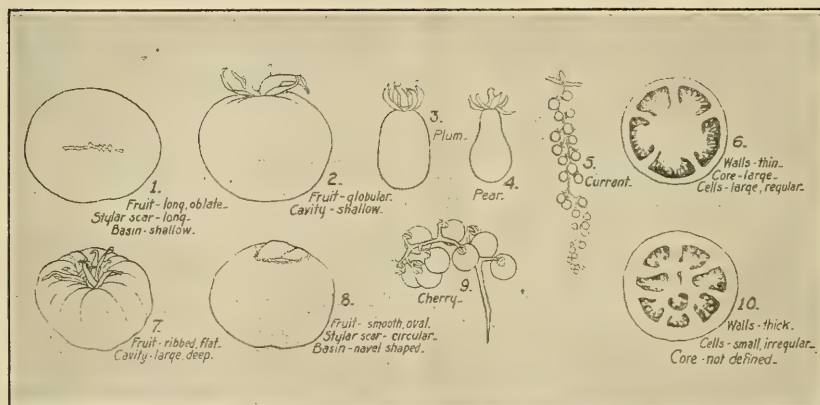


FIG. 1.—Illustrating varieties of tomatoes.

there are many sorts, varying as to habit of growth and the character of vine and fruit. Generally the vines are compact, or even decidedly dwarf in habit, fairly productive, and the fruits, though varying as to size and form, are generally of good size, attractive form and color, and well suited for culinary use. (2) Preserving, in which the vines are vigorous and produce a great number of comparatively small fruits very uniformly shaped like cherry, pear, or plum and especially suited for preserving. (3) Currant or grape, in which the vines are more rampant growers, but with smaller stems and leaves and fruit, the latter borne on long stems like those of currants which often carry brilliant, red ripe fruit at the base and are still in blossom at the end.

Varieties well adapted to garden conditions and for canning are Earliana, Favorite, Beauty, Bonny Best, Chalks Jewel, Greater Baltimore, Globe, Stone, and Red Rock, the first four being especially

suiting for the home garden, while the others are of good quality and are especially suited for canning.

Study questions: What varieties of the commercial group are grown? Which have been most successful? What variety is grown by the canning-club members? Have at hand a few specimens of each variety found in the community. Compare them as to size, shape, color. Record answers in a notebook.

References.—Farmers' Buls. 220, pp. 5, 6, 15, 18; and 642, p. 11.

Practical exercises.—Have each member of the class bring a few specimens of each variety of tomatoes grown in the community. These should be used in connection with the study questions. Require the pupils to practice until they are able to recognize each variety at sight.

Correlations.—Language: Have members of the class describe the fruits of the different varieties of tomatoes found in the community.

Drawing: Require the pupils to make drawings of the tomatoes brought to class for study.

LESSON THREE.

TOPIC: HARVESTING.

MONTH: SEPTEMBER.

Lesson outline.—Condition of fruit: If intended for home use, local market, or canning the fruit should be allowed to fully mature on the vine; if for distant market, the fruit should be picked as soon as it begins to turn red.

Picking: Exercise care in handling to avoid bruising or otherwise injuring the fruit. Remove stems to avoid puncturing the ripe fruit.

Packing: Rough, cracked, and deformed fruits should be separated from those intended for market. The best prices are received for those most nearly uniform in size, shape, and color. For a fancy product wrap each fruit in thin paper and pack in half-peck peach or tomato baskets. Fruit for canning should be thoroughly ripe but not soft. Underripe tomatoes give a straw-colored product. Overripe give a mushy product.

For seed, carefully select those plants on which the largest proportion of the crop is of desirable form and color, and save the best fruit from each plant separately. Such seed will give much better results than that from superior individual fruits from plants on which much of the fruit was inferior. Let the fruit get fully ripe, quite past condition for table use. Squeeze out the pulp and seed, throwing away the skins and flesh. Allow the seed to stand in a warm place for 1 to 3 days, according to the weather conditions, then add four or five times its bulk of water. Stir vigorously, allow it to settle, then carefully pour off the water carrying what pulp it will, and repeat until the seed is

clean. Spread out not over three seeds deep to dry, stirring repeatedly until dry.

Study questions: For what purposes are tomatoes grown by the pupils and by the community? For local market? For distant market? For canning? What receptacles are used in picking? What care is exercised in preparing tomatoes for the market? What kinds of packages are used for shipping? Do club members and people of the community select their own seed or buy seed in the market? Describe the local method of selecting and saving tomato seed. Record all answers in a notebook.

References.—Farmers' Buls. 220, pp. 13, 14; and 642, pp. 10, 11.

Practical exercises.—(1) The club members and pupils with home work with tomatoes should be busy picking, marketing, and canning tomatoes. Market and can the select fruits and convert the rough, cracked, and uneven fruits into other products. (2) Select and store choice tomato seed from thrifty, productive, healthy plants.

Correlations.—Language: Written work is provided in connection with the study questions.

Drawing: Make sketches of choice tomato plants, of select fruits, and of shipping packages.

Geography: Locate on the map canneries in the community, county, or section. In what distant markets are tomatoes and canned products of club members sold? Over what railroads are they shipped? Locate these on the map.

Arithmetic: Develop problems on the cost, value, and profit or loss of the experiences of club members. Base the exercises on the yearly reports.

LESSON FOUR.

TOPIC: JUDGING.

MONTH: SEPTEMBER.

Lesson outline.—The plant: The "form" of the plant has reference to the habit of growth. Standard varieties differ from dwarf varieties in this respect. In judging the form of a given plant it should be compared with an ideal plant in habit of growth. "Vigor" is the ability of a plant to thrive under suitable conditions. Thriftiness is indicated by the appearance of the plant and the fruit it bears. The "foliage" should be heavy to be able to resist the hot sun of mid-summer days, and diseases. "Productiveness" needs no explanation. Great stress should be laid on this quality. Some sorts of tomatoes are more subject to "disease" than others. Hence a place is given in the judging record to this point. Both the plant and its fruit should be examined carefully in this connection.

The fruit: The "shape" of the fruit should be ideal for the variety. "Smoothness" is an important quality. The condition (fig. 2) of the

blossom and the stem ends should be included when considering smoothness. The shade of "color" should be uniform and true to the variety. A poor color and an inferior skin are serious objections. The "flesh" should be solid, uniform in color, and should compose a relatively large proportion of the tomato. In other words, the amount of pulp and seed should be relatively small. Each fruit should be evenly "ripe." The "sample" should be uniform as to size, shape, and color.

Study questions: What is the object of judging tomatoes? What is meant by form? Vigor? Shape? Flesh? Pulp? Uniformity

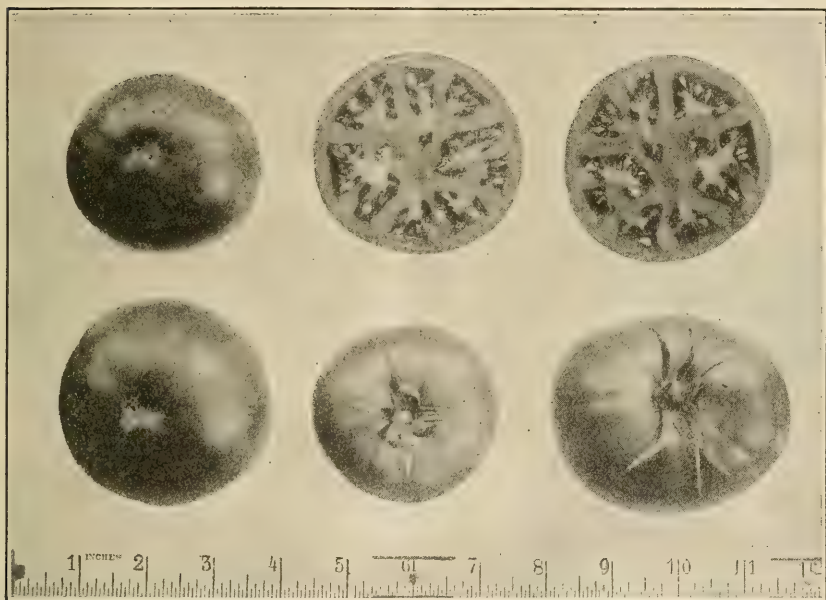


FIG. 2.—Tomatoes having desirable blossom ends and stem ends; also proper proportion of meat and pulp. The range of sizes is desirable.

of color? Why are grooves objectionable? Why is smoothness of surface desirable?

References.—U. S. Dept. Agr. Bul. 132, p. 37.

Practical exercises.—(1) Go with the members of the class to a near-by tomato plat and score some select plants. If this is impracticable, have each member of the class bring to school a choice plant to be judged. (2) Have each member of the class bring to school five choice tomato fruits to be judged. Each tomato of the group of five should be examined carefully and judged separately. Then the group as a whole should be judged. Pupils should be required to judge and grade miscellaneous lots of tomatoes. Canned tomatoes either in glass or tin should be brought to school and judged. This practice is very important, as it enables the pupils to become familiar with standard or first-class product. The pupils

should provide themselves with score cards similar to the following and use them in judging both the plants and the fruits:

SCORE CARD FOR TOMATO PLANT.

Variety.....

Points.	Perfect score.	Student's score.	Corrected score.
Form.....	10	.....	.....
Vigor.....	25	.....	.....
Foliage.....	10	.....	.....
Product (quantity and quality).....	35	.....	.....
Disease (plant and product).....	20	.....	.....
Total.....	100	.....	.....

Remarks.....

Name of pupil..... Date.....

SCORE CARD FOR TOMATOES—PLATE.

Variety.....

Points.	Perfect score.	Student's score.	Corrected score.
Shape (should be ideal for variety).....	15	.....	.....
Blow or blossom end (small scar on smooth).....	10	.....	.....
Stem end (small, slight depression).....	10	.....	.....
Color (uniform and ideal for variety).....	15	.....	.....
Flesh (solidity).....	10	.....	.....
Flesh (uniform color).....	10	.....	.....
Even ripening for individual fruits.....	15	.....	.....
Uniformity of sample.....	15	.....	.....
Total.....	100	.....	.....

Remarks.....

Name of pupil..... Date.....

SCORE CARD FOR TOMATOES—CANNED.

Variety.....

Points.	Perfect score.	Student's score.	Corrected score.
Solids:			
Fruit, ripe.....	10	.....	.....
Fruit, whole or in large pieces.....	10	.....	.....
Fruit, uniform in quality and type.....	10	.....	.....
Meat, solid and free from green or defects.....	5	.....	.....
Flavor, natural.....	10	.....	.....
Color, natural.....	10	.....	.....
Peeling and coring.....	5	.....	.....
Weight, 22 ounces in No. 3 can.....	15	.....	.....
Liquid:			
Natural consistency.....	5	.....	.....
Weight, 14 ounces in No. 3 can.....	15	.....	.....
Container:			
Free from rust or clean.....	2	.....	.....
Free from dents or blemishes.....	2	.....	.....
Label clean.....	1	.....	.....
Total.....	100	.....	.....

Remarks.....

Name of pupil..... Date.....

Correlations.—Written work is provided in preparing score cards. Practice in preparing sheets for the tabulation of facts is an important exercise.

LESSON FIVE.

TOPIC: PLACE OF TOMATOES IN THE ROTATION.

MONTH: SEPTEMBER OR OCTOBER.

Lesson outline.—Tomatoes should not be grown on the same land year after year, as some diseases live over winter in the soil and injure the new crop. The soil should be kept in good condition by including in the rotation leguminous crops. Potatoes, eggplants, and peppers should not follow tomatoes, as some of the same diseases affect all these plants. A cover crop of crimson clover, rye, or oats and vetch should follow the tomato crop. A crop of beans, peas, cabbage, or corn should precede tomatoes.

Study questions.—Why should tomatoes not be grown on the same land year after year? What insect pests and diseases of tomatoes are found in the community? What place does the tomato occupy in the rotation practiced in the community. Name a good rotation course including tomatoes for a garden or a small plat; for field crops.

References.—Farmers' Bul. 642, p. 8. Write to the State college of agriculture for suggestions as to a rotation including tomatoes.

Practical exercises.—Club members and pupils with home work should plant on their plats a cover crop of crimson clover, rye, or oats and vetch.

Correlations.—Written work is provided in preparing statements of rotation courses.

Drawing.—Have members of the class draw to scale an outline of a plat of ground containing three-tenths of an acre. Make three divisions of this and indicate on the divisions the crops of a three-year rotation including tomatoes.

Arithmetic: If the plat containing three-tenths of an acre is 36 yards wide, how long is it? How many square feet in a tenth of an acre? If a tenth of an acre is 33 feet wide, what is its length?

LESSON SIX.

TOPIC: HOTBED AND COLD FRAME.

MONTH: JANUARY OR FEBRUARY.

Lesson outline.—Hotbed: The advantages of the hotbed are: (1) Tender plants may be started early; (2) tender plants started in the hotbed have the start of weeds when transplanted; (3) early vegetables are made possible; and (4) plants grown to considerable size in hotbed are not so subject to attacks of insects and diseases.

The points to be observed in locating the hotbed are (1) nearness to the water supply, (2) convenience to garden and farm buildings, (3) protection from cold winds by buildings, fences, or hedges, and (4) good drainage with southern or southeastern exposure.

The materials used in making a hotbed are (1) manure, a good proportion of which should be fresh and so thoroughly mixed as to be

uniform in composition, density, and in the amount of heat produced; (2) a frame with the rear board 4 to 6 inches higher than the front board, and (3) glass or cloth covers for the frame. For a permanent hotbed an excavation or pit 24 to 30 inches deep should be made.

Sowing seed: Sow the seeds in rows 3 to 4 inches apart, one-fourth to one-half inch apart in the row, and cover about one-half inch deep. Water the surface of the soil with a sprinkling can. Keep the hotbed covered with sash or cloth. Raise the sash during the heat of the day for ventilation. Water the bed in the morning on bright days.

Cold frame: (1) The uses of the cold frame are (a) the growing of vegetables for winter use, (b) the hardening off of the more delicate plants in early spring, and (c) starting semihardy plants, as cabbages, cauliflower, etc. (2) The points determining the location of the cold frame are (a) protection from north wind such as the south side of a building, fence, or hedge, (b) nearness to ample water supply, and (c) southern or southeastern exposure. (3) Materials for making a cold frame are (a) a frame with a board 12 to 16 inches high on the north side and 6 to 10 inches high on the south side, (b) glass, canvas, or cloth covers, and (c) very rich, thoroughly pulverized soil.

Study questions: What are the advantages of hotbeds? How are they made? What is the difference between a temporary and a permanent hotbed? Which kind is most commonly used in the community? What plants other than tomatoes are started in hotbeds? Is glass or cloth used for covers? What is the difference between a hotbed and a cold frame? For what are cold frames used? To what extent are cold frames and hotbeds used in the community? Are cold frames used to harden off tomato plants? What other plants are grown in cold frames?

References.—Farmers' Buls. 642, pp. 1-3, pp. 12-15; and 460.

Practical exercises.—(1) Club members and pupils with home work should prepare a compost heap under cover and thoroughly rot the manure to be used in preparing soil for the hotbed. Manure for furnishing heat for hotbed should be fresh, as well-rotted manure does not give off heat. (2) Make frames for the hotbed and for the cold frame. (3) Make the hotbed and prepare to sow tomato seed.

Correlations.—Have the members of the class describe the hotbed used in starting their tomato plants.

Drawing: Draw the frame to scale.

Arithmetic: If tomatoes are planted in rows 4 feet apart and stand 3 feet apart in the row how many plants are required to set one-tenth of an acre? If each plant occupies 2 square inches in the hotbed what should be the area of a hotbed sufficiently large to produce plants to set one-tenth of an acre? Find the cost of material including the cover to make such a frame.

LESSON SEVEN.

TOPIC: SOIL—KIND, PREPARATION, FERTILIZATION.

MONTH: JANUARY OR FEBRUARY.

Lesson outline.—Soil: Select level, well-drained, rich, sandy, or sandy loam soil. Avoid land that has produced diseased tomatoes, cotton, or other crops affected with root knot.

Plow the land to a good depth and pulverize thoroughly by disking, harrowing, dragging, or rolling.

Broadcast barnyard manure before plowing at the rate of 20 tons or more an acre. If well-rotted manure is used it may be applied after plowing, but it should be thoroughly harrowed into the soil. In addition to the barnyard manure apply per acre the following just before setting the tomatoes: 100 to 150 pounds sodium nitrate, 500 to 1,000 pounds of 16 per cent acid phosphate, and 150 to 300 pounds of muriate of potash per acre. Where manure is not used apply 400 to 800 pounds of cottonseed meal per acre in addition to other fertilizers. Broadcast large amounts of fertilizers; drill small amounts. A good formula for tomatoes is 8:2:6 (8 per cent phosphoric acid, 2 per cent ammonia, and 6 per cent potash).

Study questions: What are the principal types of soil found in the community? Which type is used in growing tomatoes and other truck crops? What is the practice as to the preparation of soil for tomatoes? Other vegetable crops? What fertilizers are used for tomatoes? What value has barnyard manure other than furnishing plant food? Why should barnyard manure be plowed into the soil some months before planting time? What are the three essential elements in fertilizers? Name the source of each in the materials suggested in the lesson outline.

References.—Farmers' Buls. 220, pp. 10, 11, 12, 16, 17, 28, 29, 30; 642, pp. 5, 6; 255 and 647.

Practical exercises.—The members of the class that have decided upon growing tomatoes as club work or home work should select the plat, broadcast manure, and plow the land to a good depth. Harrow the land thoroughly. Secure commercial fertilizers. Have everything ready when the time comes to set the plants.

Correlations.—Copy in the class notebook all answers to "study questions." Draw to scale the plat to be used for growing tomatoes.

Arithmetic: Find the cost of barnyard manure used on the plat.

If sodium nitrate contains 16 per cent nitrogen, acid phosphate 16 per cent phosphoric acid, and muriate of potash 50 per cent potash, how many pounds of each in 150 pounds of sodium nitrate, 1,000 pounds of acid phosphate, and 300 pounds muriate of potash? Find the cost of the materials if a pound of nitrogen is worth 17 cents a pound, a pound of phosphoric acid 5 cents, and a pound of potash 5 cents.

LESSON EIGHT.

TOPICS: HARDENING OFF PLANTS; PREPARING LAND AND TRANSPLANTING.

MONTHS: MARCH TO MAY.

Lesson outline.—Hardening off plants. Where plants are grown in a hotbed they should be hardened before being set in the open. This can be done by transferring the plants from the hotbed to the cold frame or by removing the hotbed sash during the day. As the plants become hardened the cover may be kept off at night when there is no danger of frost. Boxes and tin cans may be used for developing the plants.

Preparing land and transplanting: Thoroughly harrow the soil. Mark off the rows about 4 feet apart for horse cultivation; 3 feet apart for hand cultivation. If plants are to be pruned to one or two stems and tied to stakes or trellises, set them 2 to 3 feet apart. If the plants are not to be pruned and staked, set them 3 to 4 feet apart. Before removing plants from the hotbed or cold frame, thoroughly soak the bed in order that considerable soil will adhere to the roots of the plants. Take up plants with trowel or spade and pack in boxes to carry to the field or plat. Set plants in the furrow and pack the soil around them. Finish filling the furrow with a turn plow or hoe.

Study questions: What methods are used to harden plants? Why should plants be hardened before setting in the open? What is the distance between rows? Between plants? Why should the soil of the hotbed or cold frame be thoroughly moistened before plants are removed? Should the soil be moistened around the plants where set in the field? Why should dry soil be spread over the moistened area?

References.—Farmers' Buls. 220, pp. 9, 16; 642, pp. 6, 7; 255, and 647.

Practical exercises.—The members of the class who are growing tomatoes should harden their plants and get them in condition to set in the open. By removing the plants from hotbeds to cold frames (tin cans or boxes), they may be given greater distance and encouraged to grow more rapidly. As a rule the plants should not be set in the open before May. However, in the far South they may be set as early as March or April. In southern Florida planting in the fall is practiced.

Correlations.—Copy in the class notebook answers to "study questions." Develop further problems on the cost of fertilizers and the number of plants required to set given areas. An accurate record of labor, cost of fertilizers, seed, and the like, should be kept in a bound book.

LESSON NINE.

TOPICS: TRAINING, PRUNING, AND CULTIVATING.

MONTH: MAY.

Lesson outline.—Training: Immediately after the plants are set a stake (fig. 3) should be driven down securely by each one of them. For this purpose use saplings, mill edgings, or inch strips. As the



FIG. 3.—Tomato plants properly trained by use of posts and twine.

plants grow tie them to the stake with soft twine. This is accomplished by looping the string around the stake and tying the tomato plant loosely so as not to interfere with its growth. Frames may be used instead of stakes, but they are much more expensive and no more satisfactory. Frames should be about 18 inches square at the base and 24 inches square at the top. Set the frames before the plants begin to spread.

Pruning: Prune the plants to one or two main stems. Remove all shoots that grow in the axils of the leaves; that is, between the leaves and main stems. To keep the shoots pinched off, go over the plat once every week or 10 days.

Cultivating: Give the tomato plants frequent shallow cultivation to keep down weeds and maintain a soil mulch to prevent evaporation. Cultivate as soon as the soil is sufficiently dry after each rain. Do not allow a crust to form. A small-tooth cultivator is suitable for tomato cultivation. By the use of the hand hoe keep the soil loose and the weeds between the plants down.

Study questions: What materials are used for stakes? Are frames used? How are they made? What points are to be gained by pruning plants to one or two stems and supporting them to stakes? Does the fruit mature earlier? Is the fruit larger? Are the plants and fruits as subject to disease when trained in this way? What are the shoots that develop in the axils of the leaves? When do the fruit stems develop? What is a "mulch?" What is a "soil mulch?" How produced?

References.—Farmers' Buls. 220, pp. 8, 9, 16; 642, pp. 7, 8; 255 and 647.

Practical exercises.—Preparing stakes, making frames, setting stakes or frames, pruning plants and cultivating the plat provide work for the members of the class with tomato plats as home or club work.

Correlations.—Written work is provided by copying in the notebook answers to "study questions."

Drawing: Make sketches of a frame; a properly pruned and staked tomato plant.

Arithmetic: Find the cost of material and labor in staking a tenth of an acre of tomatoes. Find the cost of material and labor in making frames for 200 tomato plants.

LESSON TEN.

TOPIC: PESTS—DISEASES AND INSECTS.

MONTH: MAY.

Lesson outline.—Diseases: Among the principal diseases of tomatoes are blossom-end rot, leaf spot (leaf mold), fruit rot, wilt, and root-knot. To prevent diseases practice a rotation course extending through three or four years and not including tomatoes, eggplants, and peppers more than once in this period. Fertilize and cultivate the plants well to keep them in a thrifty condition. Avoid the use of fresh manure. Pull up and burn all diseased plants when disease first appears. Begin spraying the plants with Bordeaux mixture as soon as they are set out and keep this up at intervals of 10 days for five or six applications. Fruit rot is combated by pruning and training, together with the destruction of diseased fruits. Rotation

prevents root rot. Rotation and spraying with Bordeaux are necessary to combat wilt. As a special treatment for blossom-end rot conserve the moisture supply and irrigate if found necessary.

Insects: Among the insects to be combated in growing tomatoes are cutworms, flea-beetle, tomato hornworm, and tomato "fruit worm." Cutworms cut down the young plants as soon as set out. A good remedy is to use poisoned bait before the plants are set out. Dip some green plants such as collard or cabbage leaves, bunches of clover or weeds into a solution of one spoonful of Paris green to a bucketful of water. Scatter these over the plat for two or three days before transplanting. A mash of bran or cottonseed meal may be used for the same purpose. The flea-beetle is a tiny black, jumping beetle which feeds upon the tissue of the leaf either in the cold frame or after transplanting. To combat this insect add to the Bordeaux mixture Paris green or arsenate of lead at the rate of 2 ounces of Paris green or 10 ounces of arsenate of lead to each 10 gallons of Bordeaux. The tomato hornworm is a large green caterpillar, the larva of one of the sphinx moths. Hand picking and killing is the best way to get rid of it. The "fruit worm" in its different generations is the same thing as the cotton bollworm and the bud worm of corn. It likes these plants better than tomatoes. Tomatoes planted near corn or cotton may suffer from this worm. Corn planted in tomatoes will protect the tomatoes, as the worms like the corn better than tomatoes. It injures the tomato by boring into the fruit. Pick off and destroy the worms as well as the infected tomatoes. Spray with arsenate of lead three weeks or more before the fruit ripens and again about a week before ripening spray with Paris green.

Study questions: What tomato diseases are found in the community? How serious has been the damage from diseases? What methods have been employed successfully in combating diseases? What insects found in the community attack tomatoes? To what extent have insects proved injurious? What methods have been employed to successfully combat them? Estimate the damage done to the tomato crop of the community by diseases and insects.

References.—Farmers' Buls. 220, pp. 31, 32; 642, pp. 9, 10.

Practical exercises.—Club members should prepare and have ready stock solutions of lime and of bluestone to be mixed and used to prevent diseases of plants. See Farmers' Bul. 642, p. 10. Spraying should be done before diseases appear. If insects appear, arsenate of lead may be added to the Bordeaux mixture.

Correlations.—Copy in the notebooks replies to the "study questions."

Drawing: Require the pupils to sketch parts of plants and fruits affected by diseases.

Arithmetic: From the estimated damage to the tomato crop by diseases and insects develop problems as to the financial loss due to

damage. Problems relating to losses by club members should be given special attention.

CLUB ORGANIZATION.¹

Rules for beginning work.—(1) Secure a tenth acre of ground. This may be 132 feet long and 33 feet wide, or any other convenient dimensions, provided 4,356 square feet are included. (2) Keep a complete record of the date and the kind of work done and the time used. (3) Keep a record of expenses, charging 10 cents an hour for the club member's work, 5 cents an hour for the work of the horse, and actual cost for all hired work and supplies. Estimate the value of stable manure at \$2 a ton or two-horse wagon load. Charge \$1 for the rent of the tenth acre of land.

Business showing from tenth acre.—In addition to the detailed report contained in the Daily Record Book each club member must submit the following summary of the year's work:

1. Cost of production:

(a) Rent of land	\$1.00
(b) Preparation of tenth acre.....	.....
(c) Cost of seeds and plants.....	.....
(d) Cost of manure and fertilizer.....	.....
(e) Cost of cultivation, staking, and pruning.....	.....
(f) Cost of baskets and crates.....	.....

2. Cost of canning:

(a) Cost of gathering fruit.....	.....
(b) Cost of cans, jars, labels, etc.....	.....
(c) Cost of canning, pickling, preserving, etc.....	.....
(d) Cost of crates and baskets.....	.....

Total.....	.....
Grand total of costs.....	.....

3. Garden receipts:

(a) Receipts from fresh vegetables.....	.....
(b) Estimated value of canned vegetables.....	.....
(c) Estimated value of vegetables for home use.....	.....
(d) Value of other products of the tenth acre.....	.....

Total value of products.....	.....
Expenses deducted.....	.....

Net profit for year.....	.....
Total yield of tomatoes from tenth acre, pounds..	.....
Number of pounds, other vegetables.....	.....

	No. 10.	No. 3.	No. 2.	Jars.	Bottles.
No. cans tomatoes.....					
Other products.....					

¹ Information under this heading was furnished by the Office of Extension Work in the South States Relations Service, U. S. Department of Agriculture. For further information on organization of clubs write to the same office or the State college of agriculture.

Canning-club score.—The score for judging the work of club members is as follows:

	Points.
1. Business showing, to include.....	30
Management of crops.....	10
Yield.....	10
Profit.....	10
2. Quality.....	30
Of exhibit.....	15
Of other products.....	15
3. The Daily Record Book.....	20
4. The history of the season's work.....	20

(This should be in the form of a pretty booklet made by the girl herself to tell the story of her work.)

COMMUNITY EXHIBITS.

Importance.—Every community should have its fair day. The logical place to hold such a fair is at the school building. The school

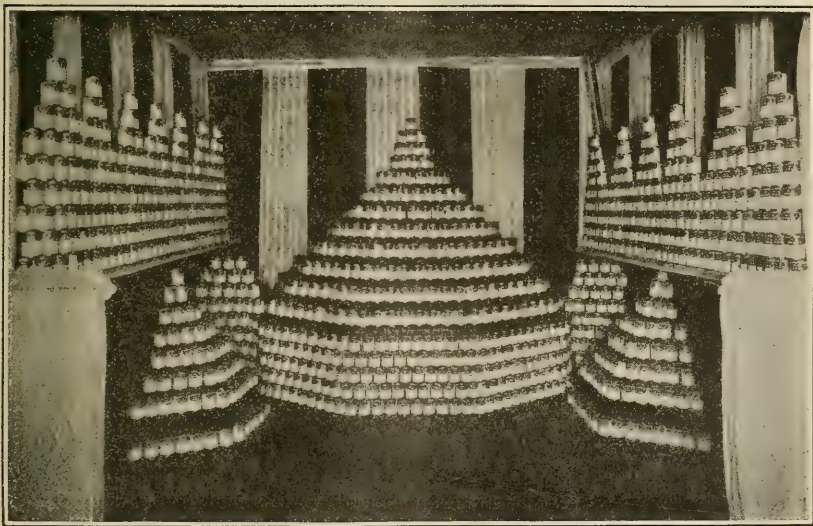


FIG. 4.—Individual canning club exhibit—1,730 cans.

should be represented. No part of the community fair can be made more instructive and attractive than the canning-club exhibit. The green and canned products of the garden lend themselves to the most striking and artistic arrangements. Looking forward to an exhibit of products and work will prove a great incentive to the pupils.

Selecting and arranging the individual exhibits.—(1) Select a plate of five tomatoes uniform in size, shape, color, and stage of ripeness. The fruits should be thoroughly ripe but not overripe. Also select a half-peck basket of tomatoes of the same kind. (2) Select and arrange a sufficient number of tins, glass cans, bottles, and jars of canned tomatoes and other tomato products to make an attractive display (fig. 4). If other vegetables have been put up, choice specimens of these products should be displayed.

While each member of the canning club should have an individual exhibit, all the members of the club should group (fig. 5) their exhibits

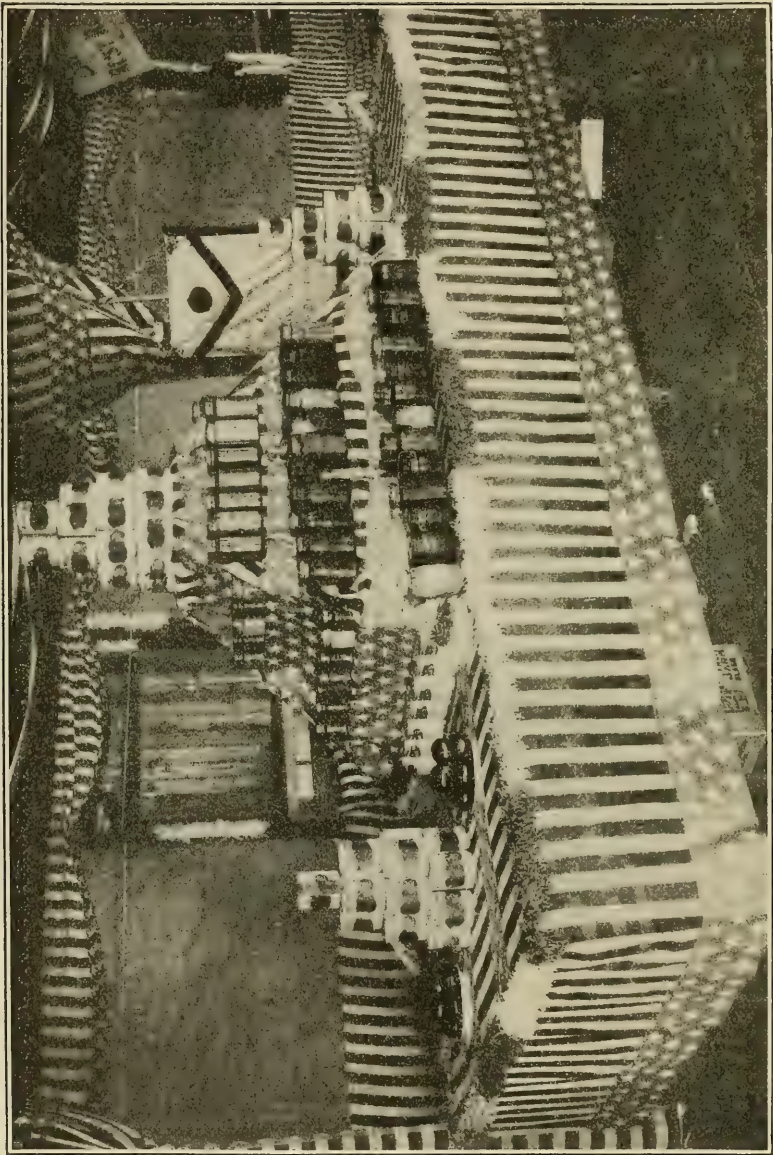


FIG. 5.—A county canning club exhibit showing tomato fruit and canned products artistically arranged.

for the general effect produced. For the group exhibit select a corner or section of the building to be used and arrange the individual exhibits so as to produce the best effect.

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October 23, 1916

ECONOMIC SURVEYS OF COUNTY HIGHWAY IMPROVEMENT.

**A Compilation and Analysis of Data in Eight Selected Counties, Showing
Comparative Financial Burdens and Economic Benefits Resulting
from Highway Improvement During a Period of Years.**

By J. E. PENNYBACKER, *Chief of Road Economics*, and M. O. ELDRIDGE,
Assistant in Road Economics.

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INTRODUCTION.

In order to obtain direct information as to the benefits and burdens imposed upon communities through the construction of systems of improved roads, it was decided in 1909 by the Office of Public Roads to make a series of exhaustive studies in selected counties. These studies were designed to cover a period of approximately 5 years, or a sufficient period to show the road improvement from its inception until such time as the full measure of its usefulness could be demonstrated. The counties selected were Spotsylvania, Dinwiddie, Lee, and Wise in Virginia, Franklin in New York, Dallas in Alabama, Lauderdale in Mississippi, and Manatee in Florida, as in those counties bonds had been recently voted for the construction of improved roads and it therefore was possible to make a series of studies to cover the road improvement from the outset to completion.

The information which has been assembled during the years 1910 to 1915, inclusive, comprises general descriptions of the character

and resources of the counties studied; the character, extent, and cost of the road improvement; the effect of the improvement on assessed valuation of property; the financial burden as indicated by tax rates; and the general prosperity and welfare of the respective counties as shown by output of local products, the character and amount of traffic, the saving in hauling costs, the incoming and outgoing shipments of freight by rail and water, the values of lands contiguous to the roads improved, the attendance at public schools, the character of school buildings, the number and distribution of population, and other related information. These studies were made at one-year intervals and, as nearly as possible, exactly comparable information was obtained on each inspection. To reenforce these records a number of representative points were selected and photographs taken each year of these same locations, thus securing a pictorial record of the changes evolved from year to year.

COMPARATIVE ANALYSIS OF THE ECONOMIC EFFECTS OF ROAD IMPROVEMENT.

Many claims and counterclaims are made as to the propriety of expending large sums of money for public-road construction in local communities. One set of extremists ascribe to good roads nearly all the benefits and blessings which fall to the lot of humanity, while another set sees in large outlays for road construction only the specter of debt and ruinous taxation. Somewhere between these two extremes must be placed the actual result produced.

The economic studies in the eight selected counties have brought out a number of features which can not fail to prove helpful examples to other counties which contemplate large outlays for road construction. A comparative analysis of the most striking data obtained in the respective studies is therefore presented under appropriate headings.

CHARACTER OF BONDS ISSUED.

In some of the counties comprised in the economic studies bonds were issued on the sinking-fund plan, and in others the serial method was followed. Analysis of the methods followed in each case brings out some interesting points. Spottsylvania County, Va., issued \$173,000 of 4.5 and 5 per cent bonds payable in 30 years, and callable after 5 years. It is impossible to estimate the total cost of retirement owing to the element of variability in the rate of retirement under this arrangement. In Dallas County, Ala., the bonds amounted to \$350,000, payable in 30 years at 5 per cent. Assuming the sinking fund to bear 3 per cent interest, as set forth in the chapter on Dallas County, the total financial burden to the county for interest and the liquidation of the bonds during the 30-year period will be

\$745,702. That the method of financing the road improvement chosen by Dallas County is not as economical as might have been selected is indicated by the fact that an equal amount of bonds at the same rate of interest, if issued under the deferred serial bond method, with the first bonds payable 6 years from the date of issuance and an equal amount payable each year thereafter for 24 years, would cost the county at the end of the 30 years \$665,000, or a difference, as compared with the sinking-fund method, of \$80,702. If 4 per cent could be realized on the sinking fund instead of 3 per cent, the saving for the deferred serial plan over the sinking-fund plan would still be \$47,216.

In the case of Manatee County, Fla., the bond issues aggregate \$250,000 and run 30 years at 5 per cent. As in this case the sinking fund also yields 5 per cent interest, the method of bonding is reasonably economical on the present basis. It is doubtful, however, if the sinking fund will continue to bring such an unusual return, and as soon as a lesser rate of interest is obtained or any of the sinking fund is not promptly invested, the sinking-fund method will become more costly than the serial method which might have been adopted.

Lee County, Va., adopted the deferred serial method, and had its bonds run from the fifth year to the twenty-sixth year. This is the only one among the entire eight which appears to have adopted the most prudent and economical method of handling the bond issue.

In Wise County the \$960,000 of 5 per cent bonds were issued for 30 years, with a 20-year redemption clause. Assuming that the bonds are retired the twenty-fifth year on the sinking-fund plan, with interest on sinking fund bearing 3 per cent, the total outlay would be \$1,858,269. If Wise County had adopted the serial method with its serial payments beginning with the sixth year and ending the twenty-fifth year, the total cost would be \$1,704,000, a saving for the serial plan over the sinking-fund plan of \$154,269. If 4 per cent could be realized on the sinking fund, the saving would still be \$72,288.

Dinwiddie County, Va., issued \$105,000 of 5 and 6 per cent bonds, payable in 30 years, but the bonds are callable after 20 years. Assuming that they will be retired at the end of 25 years on the sinking-fund plan, with interest on sinking fund at 4 per cent, the total cost would be \$218,031, whereas if they had adopted the 6-25 year serial method the cost would be \$201,100, or a difference of \$16,931.

Franklin County, N. Y., is operating at a disadvantage, as its first serial payment is not made until the tenth year. This county also has followed the rather dangerous method of extending its date of payment over a long period of years, with the result that the indebtedness long outlives the estimated life of the improvements

made. The bonds, amounting to \$500,000 at 5 per cent, run from 10 to 50 years under the deferred serial method.

Lauderdale County, Miss., which issued \$500,000 of 5 and 5½ per cent bonds, adopted the deferred serial-bond method, with the first payment coming 11 years from the date of issue and the last payment 25 years. If the county had issued the bonds on the 6-25 year basis the cost would have been \$906,875, as compared with the cost on the basis adopted of \$972,232, or a difference of \$65,367.

It would seem that the most economical form of bond to issue is the deferred serial with the first payment at the end of the sixth year and the payments then extending to a final term varying in length according to local conditions, but never exceeding 30 years. By having the first payment deferred to the sixth year the county has an opportunity to complete its road system and enjoy the benefits before beginning payment, but if the deferred period is much greater all of the evils of the sinking-fund plan with no corresponding merits are adopted. If local communities throughout the United States could profit by these examples the result would be the saving of many millions of dollars.

In one of the counties it was found that an amount probably aggregating as much as \$5,000 had been lost to the county through a premature sale of the bonds; that is, in selling the bonds before the funds actually were needed. This resulted in the payment of interest much in excess of that which could be obtained upon cash balances in bank. Counties should pay due regard to this feature of road finance, even though the necessary precautions would save only a small amount.

MANAGEMENT OF THE IMPROVEMENTS.

In the eight counties selected several forms of management were in effect and a noticeable tendency was demonstrated on the part of county authorities to select and designate for improvement a larger mileage of roads than the funds contemplated were adequate to construct. This was especially true in those counties where a considerable amount of grading was involved and where comparatively expensive types of construction were contemplated. Naturally these faulty estimates resulted in dissatisfaction and distrust among the taxpayers and to require either additional heavy outlays or the leaving of the project in a partially completed state. Judging from these examples, it is quite obviously essential that where any county contemplates comprehensive improvements involving large outlays and expensive types of construction, the detailed advice and estimate of a competent highway engineer be secured before the people are asked to approve the bond issue. In the case of the four Virginia counties the actual work of constructing the roads after the bonds

were voted was under the control of the State highway department, and it appears that excellent results were obtained commensurate with the outlay of funds; but the Virginia law was evidently defective in that no provision was made for a competent authority to make estimates and to give advice preliminary to the issuance of bonds. The Virginia Legislature has since, at its 1916 session, enacted legislation covering this point. The experience of the counties covered by these studies indicates the wisdom of a statute in each State requiring a reliable estimate upon which bond elections should be based.

The road construction in these counties would seem to bear out the assertion which has often been made that from 20 to 25 per cent of the total road mileage of a county, if wisely distributed, will serve traffic needs to the extent of at least 80 or 85 per cent of the total. In one of the counties included in these studies it will be noted that the mileage is excessively large in comparison with the ton-mileage hauled over the improved roads. In this case it would seem that the county has overbuilt its improved-road system and that a lesser mileage would have served its traffic needs.

A question partly of management and partly of finance is involved in the experience of the eight counties in regard to road maintenance. It is a well-known fact that the general tendency throughout the United States is to neglect the maintenance of roads which have, in many cases, been built at great expense. In the study of these eight counties it was found that Franklin County, N. Y., and Lauderdale County, Miss., were most effectively meeting the problem of maintenance. In the case of Franklin County the State was directly concerned in the maintenance of the roads and had complete control over such work on some of the roads and an indirect control over other roads, thus applying to the task a skilled management, the details of which are explained in the chapter on Franklin County. In Lauderdale County, Miss., the work is conducted under an excellent provision of law which specifies that an amount of not less than 1 mill on the dollar shall be levied to provide a maintenance fund for all of the roads constructed by means of bond issues, and this fund is to be kept separate from all other county funds and can be used only for maintenance. As a result of this law the Lauderdale County roads are not only in as good condition to-day as when completed, but have been actually improved. Thus the county's investment in good roads has not been allowed to deteriorate in the slightest degree.

The 1916 Virginia Legislature has met the maintenance situation by providing that an annual tax of not less than 3 per cent of the amount of bonds issued shall be levied to provide a maintenance fund. A conspicuous example of an emergency situation with reference to road maintenance is afforded by Spotsylvania County, where

no provision was made for maintenance of the bond-built roads. It was found that rapid deterioration was taking place and that insufficient funds existed with which to meet the situation. Accordingly toll gates were established on the principal roads and a sufficient revenue was derived from this source, not only to maintain the roads but to actually extend the construction a short distance. This reversion to a system long since abolished by most countries is partly due to the Virginia administrative and fiscal organization, under which the cities of the State are not taxed for county purposes (although they may aid in the improvement of roads for a distance of 10 miles from the city limits if the city council so elects). Thus it came about that while the city of Fredericksburg, in Spotsylvania County, contributed no part of the financial burden of maintaining the roads, it was, because of the heavy automobile traffic emanating from that point, a very destructive element to the county road system. In view of the very rapid development of motor vehicles during the past decade and the prospects of much more widespread use of this means of transportation in the future, the desirability of making provisions so that the cities may aid in the construction and maintenance of roads in the surrounding territory.

As to the quality of supervision, it would seem that there is little room for criticism in any of the eight counties. The work in the four Virginia counties was directed by a resident engineer from the State highway department, while the work in Dallas, Lauderdale, and Manatee Counties was all directed by special highway commissions, who, without exception, selected competent engineers and accomplished most commendable results. Franklin County, N. Y., was fortunate in having for the direction of its work a competent county superintendent, who possessed all of the practical and technical qualifications for the successful management of the work.

ECONOMIC BENEFITS TO THE RESPECTIVE COUNTIES.

In arriving at an estimate of the benefits which a county receives through the improvement of its public roads, certain factors must be taken into account more as the media by which the benefits may be measured than as the actual benefits themselves. While it is realized that the increase in the value of land must not be added to the saving in hauling costs, the convenience and access to schools, markets, churches, etc., but is rather the effect produced by those causes, it is perhaps the best index which can be obtained as to the economic value of the roads to the community. A study of the increase in the values of farm lands in the eight counties reveals the rather interesting fact that following the improvement of the main market roads the increase in the selling price of tillable farm lands served by the roads has amounted to from one

to three times the total cost of the improvements. The increase in values in those instances which were recorded ranged from 63 per cent to 80 per cent in Spotsylvania, from 68 to 194 in Dinwiddie, 70 to 80 in Lee, 25 to 100 in Wise, 9 to 114 in Franklin, 50 to 100 in Dallas, 25 to 50 in Lauderdale, and from 50 to 100 in Manatee. It will be found upon reading the chapters on the individual counties that the estimates of increase were based for the most part upon the territory within a distance of one mile on each side of the roads improved. These estimates are not claimed to be mathematically exact, but it is believed that they will give a fairly accurate indication of the results which may be expected under similar conditions.

In dealing with the effect of road improvement upon the hauling of commodities, the method has been adopted of ascertaining the traffic area served by each road much in the same manner as the drainage area of a stream is ascertained. After determining such areas the character and amount of production is ascertained and an estimate is made as to the proportion of the tonnage produced which is hauled upon the roads. A further investigation is made as to shipments by rail in and out of the county and information is obtained from United States census reports and from merchants and producers to verify the results obtained from the traffic-area calculation and the freight-tonnage inquiry. In some cases an actual traffic count or census is taken to determine the tonnage hauled upon the roads. From these various sources it is possible to arrive at a reasonably accurate estimate of the tonnage hauled over the improved roads. It is a comparatively easy matter to determine the average length of haul in each case and the prevailing rate of wages for men and teams. With these factors the total tonnage, the total ton-mileage, and the cost per ton-mile before and after the improvement of the roads are computed. The saving to traffic represented by the road improvement is thus expressed in dollars. It is of course realized that the figures given do not represent an actual "dollars and cents" saving, as many of the men and teams figured in on a wage basis might have been idle if they had not been engaged in hauling the products of farm and forest. But they at least indicate the saving in time and energy, and these have a monetary value. Therefore the saving to traffic in each county is stated for the purpose of indicating to the readers of this bulletin a relative figure by which they can determine the waste due to a system of poor roads. Considering the eight counties in the aggregate, the gross annual saving in hauling costs due to their good-roads systems affords the rather impressive total of \$627,409 for a traffic of 3,489,652 ton-miles. The average gross saving per ton-mile for the eight counties is 17.8 cents, this being

indicated by an average rate of 33.5 cents before the roads were improved, as compared with 15.7 cents after the roads were improved.

In order to determine the net saving on a ton-mileage basis, it is necessary to deduct from the gross saving the estimated annual outlay for interest and retirement of the bonds and for interest on the value of aid received from the State or from any source other than the bond issue. Table 1 gives not only the gross saving per ton-mile, but also the net saving after taking into account the cost of the improvements on this basis. It should be borne in mind that the estimated annual outlay for interest and retirement of principal may not conform strictly to the practice which may be followed in the respective counties, as instead of levying the amount which would be mathematically correct for the purpose, they may raise an unnecessarily large amount or an utterly inadequate amount from year to year. The table is based upon the amounts they should levy each year to retire the bonds under the plan by which the bonds were issued. The annual cost of maintenance should be considered as a partial offset to the saving in hauling costs if the outlay for maintenance is greater after the roads are improved than before improvement. That the cost is greater after improvement can scarcely be doubted, as real maintenance was scarcely in effect at all before the roads were improved. Definite cost data on maintenance of a comparative value for all the counties are lacking, and are, therefore, not taken into account in the table.

TABLE 1.—*Approximate saving in hauling costs on present tonnage basis after deducting annual cost of improvements during period covered by bonds.*

[Averages are weighted.]

Selected counties.	Bonds issued.	Value of State-aid contributions in convict labor.	Estimated annual outlay for interest and retirement of principal. ¹	Annual ton-miles of traffic.	Annual cost of principal and interest and convict-labor aid per ton-mile of traffic.	Hauling cost per ton-mile.		Gross saving per ton-mile.	Saving per ton-mile after deducting cost of interest and principal. ¹
						Before improvement.	After improvement.		
Spotsylvania, Va.	\$140,000	\$11,856.41	\$10,533.00	921,521	\$0.0114	\$0.300	\$0.137	\$0.163	\$0.149
Dinwiddie, Va.	105,000	37,038.32	10,573.65	833,136	.0126	.300	.150	.150	.137
Lee, Va.	455,000	21,175.48	27,967.34	297,180	.0941	.400	.200	.200	.106
Wise, Va.	960,000	.....	74,330.00	200,000	.3716	.570	.230	.340	— .032
Franklin, N. Y.	500,000	.....	21,730.00	242,145	.0897	.303	.096	.207	.117
Dallas, Ala.	350,000	.....	24,856.76	610,000	.0407	.300	.150	.150	.109
Lauderdale, Miss.	500,000	.....	33,466.66	255,378	.1310	.370	.200	.170	.039
Manatee, Fla.	250,000	.....	16,262.85	130,292	.1247	.450	.200	.250	.125
Total and average	3,260,000	70,070.21	219,720.26	3,489,652	.0629	.335	.157	.179	.116

¹ Plus interest at 5 per cent on value of State-aid contributions of convict labor.

² Exclusive of \$33,000 voted but not yet issued for Livingston and Berkley districts.

A comparison of the effect of the road improvement upon country schools affords probably a more complete vindication of the outlay than even the material features which have been presented. Combining the results obtained in all of the eight counties, it appears that before the roads were improved the average school attendance was 66 pupils of each 100 enrolled, as compared with 76 after the roads were improved. A consideration of this showing must reveal the fact that the good roads have been materially responsible for the education of 10 children out of each hundred. As the struggle for existence becomes keener in the years that are yet before us, the educational training which the children receive in the country schools will make itself felt more and more in the material and moral success of the man and woman. Not only have the roads contributed toward a larger school attendance, but they have been quite instrumental in lifting the standard of instruction by making easier the consolidation of little one-room schools into graded schools. In Dinwiddie County the system of taking the children to and from school by means of wagons has been adopted since the roads were improved. (See Pl. XI, fig. 2.)

Taking it from all of these angles, the experience of the eight counties has demonstrated that the beneficial effects of the road improvement justified the outlay, and that while more efficiency and economy might have been obtained in some cases, the loss was not such as to make the citizens of any of the counties feel that the move for better roads had been an unwise one. (See Tables 2 and 3.)

TABLE 2.—Road mileage.

State and county.	Total of all roads.	Miles of road per square mile of area.	Surfaced.		Graded under bond issue.	Total graded or surfaced.
			Under bond issue.	Total.		
			<i>Miles.</i>	<i>Miles.</i>	<i>Miles.</i>	<i>Miles.</i>
Virginia:						
Spotsylvania.....	400	0.97	176.73	82.73	0	82.73
Dinwiddie.....	524	1.01	291.3	101.06	0	101.06
Lee.....	450	1.00	139.26	44.86	160.19	105.05
Wise.....	300	.71	78.47	83.07	62.75	145.82
New York: Franklin.....	1,370	.82	124.0	386.8	0	368.8
Alabama: Dallas.....	1,000	1.04	101.75	217.9	0	217.9
Mississippi: Lauderdale.....	800	1.16	96.75	146.75	0	146.75
Florida: Manatee.....	575	.43	57.25	57.25	6.4	63.65

¹ Built partly with State convicts.² Built entirely with State convicts.

TABLE 2.—Road mileage—Continued.

State and county.	Road mileage (per cent of grand total).			Character of surface.	Cost per mile.
	Surfaced only.	Graded only.	Graded or sur- faced.		
Virginia:					
Spotsylvania.....	20.6	0	20.6	Sand-clay.....	¹ \$1,150-\$1,500
Dinwiddie.....	19.3	0	19.3	Gravel.....	¹ 2,000-2,500
Lee.....	10.0	13.3	23.3	Gravel, sand-clay, top-soil.	1,300-1,700
				Earth.....	¹ 3,000-3,500
				Macadam.....	¹ 6,000-7,000
				Earth.....	5,700
Wise.....	27.7	20.9	48.6	Macadam.....	9,200
				Bituminous surface treat- ment.....	400
New York: Franklin.....	28.2	0	28.2	Gravel.....	1,900-2,500
				Macadam.....	3,000-4,000
Alabama: Dallas.....	21.7	0	21.7	Gravel.....	3,000-3,600
				Sand-clay.....	1,500-1,800
Mississippi: Lauderdale.....	18.3	0	18.3	Gravel-macadam.....	4,000-6,500
				Sand-clay.....	1,700-2,000
Florida: Manatee.....	9.9	1.1	11.0	Marl-rock macadam.....	3,800
				Flint-rock macadam.....	4,700
				Shells.....	2,400

TABLE 3.—Road bonds and taxation data.

State and county.	Bonded debt incurred for roads.			Term of bonds in years.	Interest rate on bonds.	Average rate of tax per \$100 of assessed valuation.			
	Total to 1915, inclusive.	Per capita.	Per \$100 as- sessed valuation. (1915)			All pur- poses.		Road bonds.	
						1910	1915	1910	1915
Virginia:					<i>Per ct.</i>				
Spotsylvania.....	\$173,000	\$10.93	\$4.97	2 5-30	4½-5	\$1.20	\$1.70	\$0.45	\$0.625
Dinwiddie.....	105,000	2.66	1.75	4 20-30	5-6	1.20	1.20	0	.10
Lee.....	455,000	19.08	9.15	5 5-26	5½	1.40	1.96	0	.61
Wise.....	960,000	28.10	7.04	4 20-30	5	1.40	1.762	0.30	.562
New York: Franklin.....	500,000	10.92	3.66	5 10-50	4½-5	(⁶)	(⁶)	(⁶)	(⁶)
Alabama: Dallas.....	350,000	6.57	2.48	7 30	5	1.35	1.40	0	.176
Mississippi: Lauderdale.....	500,000	10.65	3.08	5 10-25	5-5½	1.54	1.66	0	.16
Florida: Manatee.....	250,000	26.17	3.09	7 30	5	2.65	2.60	.70	.30

¹ Amount authorized but only \$140,000 sold.² Callable after 5 years.³ Average for two districts only.⁴ Deferred serial with sinking-fund provision.⁵ Deferred serial.⁶ Taxes levied by towns and vary in each.⁷ Sinking fund.⁸ No special levy made for road bonds, but an average rate of 17.6 cents on the \$100 will pay interest and create sinking fund with which to retire bonds in 30 years.

SPOTSYLVANIA COUNTY, VA.

Two districts in Spotsylvania County, Va., on November 2, 1909, voted an aggregate of \$100,000 in bonds for the construction of improved roads. For 44 years following the close of the Civil War the farm land in the county had been allowed gradually to revert into a wilderness of second-growth timber, and it was not uncommon to see great stretches of woodland with traces of ancient furrows still visible. Lands were held at from \$5 to \$15 per acre,

with few buyers even at those figures. Most of the agricultural products which the farms in the county were capable of producing were brought in by rail from the outside, and thus steadily the balance of trade was rising against the county. Its greatest source of wealth—namely, timber and crossties—could not be utilized to the best advantage because the roads for many months in the year were almost impassable. The economic studies to ascertain the relative benefits and burdens of the road improvement in the county were begun in 1910 and continued annually thereafter up through 1915. A significant incident on the first inspection trip, March, 1910, occurred within a half mile of Fredericksburg, when the horses broke a singletree in their attempt to pull the light surrey, with its two passengers and driver through the deep, heavy, clay mud. (See Pl. III, fig. 1.)

While it seemed apparent at the outset that the building of a system of improved roads would be highly beneficial to the county, it remained to be seen whether the financial outlay involved would be heavier than the corresponding benefits received and whether good management and sound economy would be practiced, so as to get the greatest possible results for the outlay of funds. Only by determination of these questions could the example of Spotsylvania County be made useful to other communities which should find it necessary to deal with the subject of road improvement. As the investigations were begun before any initial steps were taken in the matter of management or construction, it was practicable to record year by year the story of Spotsylvania's good-roads progress and the economic results of the project.

It might be well to mention that Spotsylvania County is located about 45 miles north of Richmond and has an area of 401 square miles. The principal products are timber and crossties, although the farms produce some bright tobacco, hay, potatoes, truck, small fruits, etc., and since the roads have been improved there has been some development of the dairy and poultry industries. There are no large manufacturing industries and no cities except Fredericksburg, which had a population in 1910 of 5,874 out of a total population for the county of 15,809. Primarily the problem was to provide a system of roads which, while used for hauling the forest products, gradually would develop the agricultural resources of the county.

HOW THE IMPROVEMENT WAS FINANCED.

Owing to the fact that under the Virginia law cities are not taxable for county purposes, Fredericksburg, the only city in Spotsylvania County, could not be reached for a proportionate share of the proposed outlay. There were four districts in the county, but only two, namely, Courtland and Chancellor, actively took up the move-

ment. In consequence the financial burden rested at the outset entirely upon the two districts named, although traffic from the other two districts passed over the roads of these two in going to and from Fredericksburg. In spite of these drawbacks, Courtland district voted \$60,000 and Chancellor district \$40,000, and the bonds were sold at intervals between February 8, 1910, and September 17, 1912. The first \$18,700 issued carried $4\frac{1}{2}$ per cent interest and the remainder carried 5 per cent interest, payable semi-annually. All of the bonds were to run 30 years, but were callable after 5 years. In all cases the bonds brought par and accrued interest. Callable bonds ordinarily do not bring as high a price in the bond market as noncallable bonds which are payable at definite periods. This indicates that the bonds were marketed shrewdly and intelligently. Arrangements were made to secure 3 per cent interest from the banks on sinking funds. Even then marketing of the bonds would not have been accomplished except for the loyal support given by local investors. Furthermore, as pointed out in the preceding chapter of this bulletin, the combination of long-term and a call provision leaves so much to the discretion of the local authorities from year to year as to inject an element of uncertainty into the matter of bond retirement and tax levies. It might readily occur that when officials are in authority who are actuated by an eagerness to get the district out of debt, an excessive tax rate would be levied and the bonds called in at an unnecessarily rapid rate; or the reverse might be true if negligent officials, or those who, for any reason, might desire to hold the tax rate down to a minimum, should neglect to call in bonds. The district then would carry the burden represented by the difference between the 3 per cent obtained on sinking fund and the 5 per cent carried by the bonds. It would have been better if a 5-30 year deferred serial bond had been adopted, as the annual retirement then would have been fixed and the tax rate subject to no wide fluctuation.

Our subsequent investigations enabled us to see just what financial steps were taken in connection with the bond issues. As the bonds were not callable until after 5 years, it followed that the first call year was 1915. If it were intended that the payment on the debt should begin in 1915 and extend to the thirtieth year the logical plan for Courtland and Chancellor districts would be to pay off \$4,000 of the principal each year, from the sixth to the thirtieth year. For the two districts for 1915 this would require an average rate of 32.7 cents on each hundred dollars of taxable valuation for interest and principal for the 30-year period. Of course this rate would decrease as the assessment increased at 5-year intervals.

The plan actually followed in Courtland district was to levy 40 cents on the hundred dollars for 1910 and 1911; for 1912, 45 cents; for 1913,

70 cents; for 1914, 35 cents; thus producing a total of \$25,243.49, to which should be added whatever was obtained from the 3 per cent allowed by the banks on sinking-fund deposits. Inasmuch as the interest for the first 5 years amounted to only \$14,517.50, this left \$11,725.99 plus the interest on the sinking fund. With this amount, \$11,000 of the bonds had been retired at the beginning of 1915. A levy of 65 cents on the hundred dollars was made in 1915, from which \$9,917.50 was obtained, and on December 13, 1915, the bonded debt was further reduced to the extent of \$2,000. At the rate of payment and taxation thus far adopted, the district will be out of debt long before the expiration of the 30-year term; but whether this rapid payment is desirable under all existing conditions must remain a matter of judgment.

An inspection of tax rates shows that in 1910 the taxpayers of Courtland district paid, exclusive of the 40 cents levied for road bonds, a total of 95 cents on the hundred dollars, or a total for all purposes, including State, county, and road-bond taxes, of \$1.35, of which the bond taxes formed 29.6 per cent. The levying of a 65-cent tax rate in 1915 made the total tax for that year \$1.70 on the hundred dollars. Thus the road bonds in 1915 formed 38.2 per cent of all taxes paid in Courtland district. In both years the general road and bridge tax was 15 cents on the hundred dollars.

To see how this would affect the individual taxpayer, let us assume that a man owns a \$5,000 farm, which is assessed at \$3,000, or a little more than the usual basis of assessment in the county. He will pay taxes for all purposes in 1915 at \$1.70, a total of \$51, of which \$19.48 will represent his share of the tax for the improved roads. This 65-cent rate is higher than the average, however, and it would seem more equitable to estimate his tax burden at 40 cents on the hundred dollars, as was levied in 1910. This would make his annual outlay for the improved roads \$12. Against this cost he must place the saving in wear and tear of his teams and wagons, the opportunity which he has gained of hauling larger loads, of doing his hauling at all seasons of the year, and of saving time in making his trips to market. It is safe to say that the average possessor of a \$5,000 farm would gladly pay such a tax per year in return for a guarantee of these benefits.

Chancellor district, which voted \$40,000 in bonds, levied a still higher rate of tax for bond purposes than Courtland, as the rate was 50 cents for 1910 and 1911, 55 cents for 1912, and 65 cents for 1913, 1914, and 1915. The total tax rate for 1910 was \$1.40 for all purposes, State, county, and bonds, and in 1915 was \$1.85. Thus the bond-issue tax comprised 35.7 per cent of the total in 1910 and 35.1 per cent of the total in 1915. During the 5-year period from 1910 to 1914, the district raised \$15,865 to apply to the bonds, of which

about \$9,500 was needed for interest, leaving about \$6,360, plus interest obtained on sinking fund, to apply on the principal. From this sum \$4,000 of the bonds were retired by 1915, and after the 1915 levy was obtained, which yielded \$4,838, a further \$2,500 of bonds were retired.

While more than ample provision was made for rapidly paying off the bonds, no steps were taken in either district properly to maintain the roads after the completion of the system. It was soon found that if the roads were to be prevented from going to destruction and the investment thus dissipated, it was necessary that funds be provided for maintenance. As the tax rates were already high, the situation was met by the establishment of toll gates. The operation of the toll system, described elsewhere in this chapter, produced an amount equivalent to that which would be obtained by a tax levy of 31 cents on the hundred dollars of the 1915 assessed valuation, if levied against the whole county, or 50 cents if levied against Courtland and Chancellor districts alone. After deducting that portion of the toll funds which was applied to new construction, the funds actually applied to maintenance were still sufficient in amount to be equivalent to a sum which could be raised by a tax rate of 17.4 cents on the hundred-dollar valuation, for the whole county, or 28.1 cents for these two districts alone. Possibly a lower rate for the bond retirement and the application of the saving thus made to the maintenance of the roads might have been desirable rather than the establishment of the toll system, but the existence of other factors, however, bearing upon the subject of tolls in Spotsylvania County complicate the question so that it can be dealt with by the local community only as a special problem.

OTHER DISTRICTS VOTE BONDS.

Stirred by the example of Courtland and Chancellor districts, the two other districts in the county, namely, Berkley and Livingston, voted \$40,000 and \$33,000 respectively in 1913.

COUNTY VALUATIONS AND REVENUES SHOW LARGE INCREASE.

In 1910 the tax rates for all purposes, including State tax of 35 cents, were respectively, \$1.35 for Courtland, \$1.40 for Chancellor, \$1 for Livingston, and \$1.05 for Berkley, or an average of \$1.20 for the county, with a total revenue production of \$31,571. The rates had increased in 1915 to \$1.70 in Courtland, \$1.75 in Chancellor, \$1.45 in Livingston, and \$1.90 in Berkley, or an average of \$1.70, with a total revenue produced of approximately \$59,100. It is interesting to note, therefore, that while the tax rate increased 41.6 per cent in the period from 1910 to 1915, the revenue increased 87.2 per cent. This is due to the very large increase in the assessed valuation of property since the road-building program was begun, and

shows that while the people are paying taxes at a higher rate, they are obtaining far more in the form of revenue for public purposes than the increase in the tax rate ordinarily would have yielded. As an index to the prosperity of the county since the completion of the road system, it might be pointed out that the taxable valuation in 1905 was \$1,738,727; in 1910, \$2,120,753; and in 1915, \$3,478,373. The increase in the five-year period from 1905 to 1910, the year road improvement was begun, was only 21.9 per cent, the increase in the corresponding period from 1910 to 1915 was 63.9 per cent. Probably a better conception of this increase can be gained through the statement that the aggregate of the bond issues for the four districts, comprising the sum of \$173,000, is less than one-eighth the increase in valuation with a considerable portion of these bond issues yet to be expended.

HOW THE WORK WAS MANAGED.

The funds derived from the bond issues in Chancellor and Courtland districts were expended under the direction of the special board of public roads of Spotsylvania County, and a resident engineer, at \$1,200 per annum, who was appointed by the State highway commissioner for the period of construction only. The board consisted of four members appointed by the judge of the circuit court for a term of three years. Each member was paid \$100 a year, except the secretary-treasurer, who was paid \$125. Orders for expenditures originated with the engineer in charge and were approved by the board. A similar board has charge of the work in Livingston and Berkley districts.

The roads to be improved were designated by the judge of the circuit court in the order of election. When the improvement is completed and accepted by the State highway department and county road board, the roads are turned over for maintenance to the county board of supervisors, composed of one supervisor from each magisterial district, elected for a term of 4 years, and receiving a compensation of \$4 per day for time actually employed.

Under the Virginia law all roads built by means of bond issues are under the direction of the State highway department as to surveys, plans, specifications, and supervision of construction. The State also grants aid in the form of cash or convict labor to the extent of one-half the cost of the roads, but as the amount of cash annually available from the State is small, it will probably require a number of years to reimburse this county to the extent of one-half the total outlay. The State money aid was not expended on the bond-issue roads, but on other roads, and is only mentioned to make clear the relation between the bond-issue funds and the State-aid allotments. From 1909 to 1915 a total of \$8,212.01 in money aid and automobile licenses has been received by the county.

The regular road work of the county is carried on under the direction of a superintendent appointed by the board of supervisors and receiving a salary of \$1,200 per annum, house rent free, and transportation. The superintendent hires all labor and teams and purchases machinery, equipment, and materials on the approval of the board of supervisors.

Three main highways radiating from Fredericksburg and aggregating, with their branches, 39.5 miles, were selected for improvement and the actual routes were set forth in the order of election. These roads, located in Courtland and Chancellor districts, were improved from funds derived from the \$100,000 bond issues for those districts, the amounts apportioned to each district being in accordance with the proportionate mileage in each. The first contract was awarded in July, 1910, and the last mile of road was completed in these two districts in September, 1913. By actual measurement the roads improved aggregated 40.89 miles, or 1.39 miles more than originally contemplated. This, of itself, was an unusual showing, but an even more striking evidence of the economy exercised was the fact that enough money remained of the original \$100,000 issued to construct an additional gravel road between Spotsylvania Courthouse and the southern boundary of Courtland district, a distance of 2.3 miles. This was completed in August, 1913, making a total mileage of roads completed under the bond issue in Courtland and Chancellor districts of 43.19 miles, or a little over 10 per cent of the total of 400 miles of road in the county.

The average cost per mile, including culverts and bridges, was \$2,319.21. As an example of the great improvement in bridges, see Plate IV. The roads were all constructed of gravel, except 1.7 miles of water-bound macadam, which was surfaced with gneiss of a very poor quality. This section has worn badly and most of it has since been resurfaced with gravel. The gravel used on the improved road system was composed of quartz pebbles, quartz sand, and clay of fairly good wearing quality. Table 4 is a detailed report on dimensions and costs and was supplied by the State highway commissioner of Virginia.

TABLE 4.—*Mileage and cost of roads built.*

CHANCELLOR DISTRICT.

Name of road.	Length of road.	Width of roadway.	Width of gravel.	Expended on road.	Rate per mile.
	<i>Miles.</i>	<i>Feet.</i>	<i>Feet.</i>		
Plank.....	5.250	20	14	\$8,410.91	\$1,602.08
Pike.....	4.772	20	14	9,224.05	1,932.95
Gordon.....	3.9	20	14	9,272.38	2,377.53
Catharpin.....	4.29	20	14	10,953.87	2,553.35
	18.212	20	14	37,861.21	2,080.27

TABLE 4.—*Mileage and cost of roads built*—Continued.

COURTLAND DISTRICT.

Name of road.	Length of road.	Width of road-way.	Width of gravel.	Width of macadam.	Expended on road.	Expended on culverts and bridges.	Rate per mile, including culverts and bridges.
	<i>Miles.</i>	<i>Feet.</i>	<i>Feet.</i>	<i>Feet.</i>			
Plank.....	3.039	20	14	¹ 20	\$4,968.45	\$1,173.19	\$2,020.94
Spotsylvania Courthouse to Gayles Bridge.....	1.7	20-24	-----	² 14	12,441.00	-----	7,318.23
River.....	3.106	20	14	-----	6,250.89	640.40	2,218.70
Fredericksburg-Spotsylvania Courthouse.....	10.05	20	14	-----	19,538.21	208.00	1,964.80
Telegraph Road from Fredericksburg; Courthouse Road to Massaponax.....	4.55	20	14	-----	10,886.55	688.27	2,543.92
Hazel Run-Plank.....	.223	20	14	-----	1,213.20	-----	5,440.36
Spotsylvania Courthouse-Snell's Bridge.....	2.310	20	14	-----	³ 4,297.49	-----	1,860.38
	24.978	-----	-----	-----	59,595.79	2,709.86	2,494.40

¹ For 424 feet.² For 8,525 feet.³ Includes 2,206.6 convict-labor days. Convict camp maintained at a cost of \$1,272.41, which is included in the above.

In Berkley district 25.54 miles of gravel road were constructed with the proceeds of the \$40,000 bond issue, supplemented by convict labor furnished by the State. The convict labor aggregated 15,242.5 labor days. The district paid the actual cost of 7,425 convict days at 55 cents, or a total of \$4,083.75, while the State paid the actual cost of 7,817.5 convict days at 55 cents, or a total of \$4,299.62. These roads therefore cost an average of \$1,119.43 per mile, including cash and actual cost of maintaining the convicts.

Livingston district has under construction 34 miles of soil roads, which, on the basis of 8 miles already completed, are costing \$1,155.88 per mile.

SUMMARY OF MILEAGE.

Thus far 76.73 miles of road have been improved in the four districts at an average cost, including cash outlay by all the districts and convict labor furnished two districts by the State at actual cost, of \$1,944.52 per mile, while the total outlay on this basis has reached \$149,198.80, of which the State's share in convict labor amounted to \$6,889.15 on basis of actual cost. When the road improvement has been completed in Livingston district the county will have 102.73 miles of improved roads, or about 25 per cent of the total mileage. (See Pl. II.)

TOLL SYSTEM OF MAINTENANCE ADOPTED.

The first year after the roads were improved the surfaces were rather sticky and muddy in wet weather, but this condition almost entirely disappeared after the second year, when the surplus clay had leached out. The roads are now generally in good condition.

Very little was done in the way of maintenance until 1914, on account of lack of funds. Because of opposition to a special levy for maintenance, the board of supervisors determined to raise the necessary maintenance fund by means of tolls, for which authority was secured from the General Assembly of Virginia.

On August 10, 1914, three toll gates were established, one on the Courthouse Road, one on the River Road, and one on the Chancellorsville Road, for which toll rates for round trips were fixed as follows: Single horse and vehicle, 5 cents; 2 horses and buggy, 10 cents; 2 horses and wagon, 15 cents; 4 horses and wagon, 25 cents; Ford automobiles, 20 cents; other automobiles, 25 cents to 35 cents. During the week of August 10-16, 1914, \$258.77 was collected in tolls, and on September 1 the toll rates on the Chancellorsville and River Roads were reduced one-half. The gross total collected in tolls during the first year of operation amounted to \$10,800, of which \$2,599.30, or 24 per cent, was received from automobiles. In order to raise this amount of money by direct tax it would be necessary to assess an additional tax on all of the taxable property of about 30 cents on the hundred dollars. As the total length of road on which tolls were collected was 43.2 miles in Courtland and Chancellor districts, this gave an annual gross amount per mile of \$250. From the gross amount of \$10,800 must be deducted \$1,740 for collection and overhead, leaving \$210 per mile for actual maintenance.

The total expenses of collection and overhead amounted to \$145 per month, as follows: Two collectors at \$45 per month each and one collector at \$40 per month; oil, tickets, fuel, etc., \$5 per month for each of the three gates. There is no overhead charge for supervision, as the gatekeepers report to the county superintendent of roads, whose salary is paid from the regular county funds. Out of the tollgate receipts the River Road was extended 3 miles at a cost of about \$1,200, and 3 additional miles were built in different parts of Chancellor and Courtland districts, at a cost of \$1,800, leaving \$6,060, which was used in resurfacing the Courthouse Road 11.75 miles, at an average cost of \$515 per mile.

The maintenance forces of the county under which this work was done consisted of two gangs with a foreman in charge of each gang. Both gangs used on the average 10 teams, four of which were owned by the county, one 10-ton roller, owned by the county and paid for out of the county funds, and from 14 to 15 men. The foremen of the gangs received \$2 and \$2.50 per day, respectively, and laborers were paid \$1 per day and board, or \$1.25 without board. Team hire was \$3 per day without driver, and the cost of maintenance of county-owned teams averaged about \$1 per day.

This maintenance situation emphasizes the disinclination on the part of local communities to submit to taxation for the purpose of keeping up their roads after they have gone to considerable expense to build them. The toll system appeals to them as a simple way out of the difficulty and furthermore as a means of reaching the lumber dealers and automobilists who come from other districts, counties and States.

EFFECT OF ROAD IMPROVEMENT ON LAND VALUES.

To ascertain as nearly as possible the effect of the road improvement on land values, a careful record was made in 1910 of the actual market value of 35 farms located on the roads selected for improvement. The total number of acres in these 35 farms was 5,518 and the total market value at that time was \$77,950, or \$14.13 per acre, including buildings. In the same year the average value of all land in the county, including buildings, was reported by the United States census to be \$13 per acre, thus indicating the accuracy of the data obtained by our investigation. As the road improvement had not been completed in 1911, no inquiry was made in that year as to land values, but in subsequent years careful investigation was made as to the values of the 35 farms recorded in our 1910 investigation. It was found that in 1912, 7 of the 35 farms had been sold and that an offer had been made and refused for another one of the original number. How the values had increased in the brief period of about 2 years may best be indicated by the history of these 7 cases.

A farm 3 miles from Fredericksburg, containing 139 acres and valued at \$3,500 in 1909, was sold in 1912 for \$5,000, an increase over the 1910 valuation of 43 per cent.

A farm 10 miles from Fredericksburg, containing 420 acres, listed at \$6,000 in 1910, sold for \$8,250 in 1912, an increase of 37 per cent over the 1910 valuation.

A farm 11 miles from Fredericksburg, containing 110 acres, valued at \$1,500 in 1910, brought in 1912 \$2,000 for 80 acres and \$500 for timber, an increase of 60 per cent without counting the value of the remaining 30 acres, or about 116 per cent, counting this acreage at its 1912 sale value.

A farm 2 miles from Fredericksburg, containing 101 acres, valued at \$3,000 in 1910, sold for \$3,750 in 1912, an increase of 25 per cent.

For a farm 6 miles from Fredericksburg, containing 475 acres, valued at \$5,000 in 1910, \$12,500 was refused during the latter part of 1911, an increase of 150 per cent.

The five farms above referred to are located on the Fredericksburg-Spotsylvania Court House Road

A farm 4 miles from Fredericksburg, on the Massaponax Road, containing 357 acres, valued at \$2,800 in 1910, was sold at forced public sale in 1912 for \$4,400, an increase of 76 per cent.

A farm 3 miles from Fredericksburg, on the Plank Road, containing 133 acres, valued at \$7,000 in 1910, sold for \$10,000 in 1912, an increase of 43 per cent.

Another farm, 3 miles from Fredericksburg, on the Plank Road, containing 100 acres, valued at \$3,000 in 1910, was sold for \$4,750 in 1912, an increase of 58 per cent.

It is thus evident that in this little group of sales the increase in value according to the actual record obtained was \$20,100, or 63.2 per cent, over the 1910 value. The average value, after the roads were improved, was \$28.26 per acre, as compared with \$17.31 previous to the improvement.

A confirmation of the 1912 data on land values was obtained in 1913, at which time it was found that four transfers of farm land, which took place in that year on improved roads from 5 to 10 miles from Fredericksburg, were on the basis of \$30.11 per acre, whereas they were listed in 1910 at \$13.89 per acre. It was learned in 1913 that some of the farms which had been practically abandoned by their owners as places of residence had been reoccupied. One farm owner moved to New England and rented his farm on the Chancellorsville Road. Returning in 1913 to make some repairs, he found the farm so conveniently located on the improved road that he moved back from New England.

In February, 1914, another inspection of the roads was made and a further confirmation of the effect of the improvement on land values was obtained. This 1914 record was as follows:

A farm containing 136 acres, valued at \$6,000 before the roads were improved, was sold after the roads were improved for \$12,000, an increase of 100 per cent.

For a farm containing 133 acres, valued at \$7,000 before the roads were improved, an offer of \$10,500 was made and refused after the road was improved, an increase of 50 per cent.

A farm on the River Road, containing 312 acres, which sold in 1908 for \$4,500, was again sold for \$10,500 in 1913, an increase of 133 per cent.

A farm on the River Road, containing 870 acres, sold for \$18,000 shortly before the road was improved and was sold again for \$31,000 in 1914, an increase of 72 per cent.

It appears that the 1,451 acres increased in value \$28,500, or 80 per cent, or from \$24.46 to \$44.10 per acre, and it is believed that this increase was caused very largely by the improved roads.

Taking the two groups of sales and combining acreage and value, we get a total of 3,286 acres, with a total original value of \$67,300

and a total sale value after the roads were improved of \$115,900, showing an average value per acre before improvement of \$20.48 and an average value after improvement of \$35.27, or a general average of 70.2 per cent increase in value.

In order to ascertain whether or not the increase in land values was general throughout the county, or whether it was confined to the improved roads, we obtained in the fall of 1915 values of three typical farms on unimproved roads where the land was comparable in agricultural fertility with land on the improved roads.

A farm in Livingston district, containing 1,000 acres, 12 miles from an improved road, was sold at \$7 per acre in 1914.

Another farm in Livingston district, 10 miles from the improved road, containing 148 acres, was sold in 1915 for \$9.45 per acre.

A farm in Berkley district, 12 miles from the improved road, containing 190 acres, was sold in 1915 for \$4.73 per acre.

These three farms were stated by competent authorities to be typical of values on the unimproved roads, and if the average of \$6.89 per acre for the three farms is compared with the average of \$35.27 per acre for the sales on the improved roads, it seems reasonably conclusive evidence that the roads have been a most important factor in the increase of farm values.

On the whole, it appears that the land along the improved roads increased in value an average of about 70 per cent, due far more to the road improvement than to any other cause.

Again, it was ascertained from the dealers in real estate that very few farms had been sold in the county except those located on or near the improved roads and that the increase in land values was confined almost entirely to the improved road sections. Real estate dealers in Fredericksburg asserted that they had sold more farms on the improved roads during the single year 1911-12 than in all the rest of the county combined during the preceding five years. They stated further that prospective buyers had, in many cases, refused to look at farms located on unimproved roads. Considerable areas of farming land along the improved roads are now being cultivated for the first time since the Civil War. Several tracts of land which were covered with forest growth or brush when the first inspection was made in 1910 have since been cleared and are now being cultivated. A series of photographs, taken of the same location each year since 1910, illustrates this fact. (Pl. I, figs. 1-4.)

EFFECT OF ROAD IMPROVEMENT ON TRAFFIC DEVELOPMENT.

To obtain basic data covering the development of the agricultural and forest resources of the county and to aid in determining the effect of the road improvement on such development, a careful record of incoming and outgoing shipments of farm and forest products at

Fredericksburg, the principal market and shipping point, was obtained for the years 1909 and 1913, these being the years, respectively, before the improvement was begun and after it had been fairly well completed. The 1909 record showed a total of incoming farm products of 10,520.1 tons, while the outgoing farm products amounted to only 7,255.1 tons, the balance of trade being, therefore, against the county to the extent of 3,265 tons. The 1913 inquiry indicated that up to that year there had been no favorable change in the ratio of incoming to outgoing shipments, as the total incoming amounted to 15,169.8 tons, an increase over the 1909 figures of 44.2 per cent, while the outgoing amounted to only 7,869 tons, an increase over the 1909 figures of 8.4 per cent. The explanation of this continued lethargy in the matter of agricultural development is found in a reference to the shipments of forest products. In 1909 the total forest products shipped out by rail and water at Fredericksburg was 71,915.2 tons, while in 1913 the total had increased to 128,219.2 tons, an increase of 56,304 tons or 78.2 per cent. It is evident that the people are devoting their first attention to realizing upon their great wealth of forest products, leaving the agricultural development to come later. It is worthy of mention, however, that the 1913 record as compared with 1909 shows an increase in the outgoing egg shipments of 77.3 per cent, and in the dairy products an increase of 110 per cent. Most of the farm products which are bought outside the county can be produced on the home farms, and it is quite probable that with the excellent transportation system afforded by the improved roads farming gradually will be developed and the balance of trade ultimately be in favor of the county instead of against it.

Considering the data of freight shipments as an index to determine the increase in traffic hauled on the country roads, it would indicate that this increase between 1909 and 1913 has approximated 70 per cent. To ascertain, however, the volume of traffic before and after improvement of the roads and the effect of the road improvement on the cost of hauling, records were made of the traffic encountered on the roads at each of the annual inspections, extending from 1910 to 1915. The following record (Table 5) of traffic encountered on the roads in March, 1910, indicates strikingly the poor condition of the roads and the excessive burden imposed upon traffic in delivering even small quantities of products at markets:

TABLE 5.—*Approximate weight of traffic encountered on roads in Spotsylvania County, Va., in March, 1910.*

	Pounds.
1-horse wagon loaded with 2 cross-ties	400
1-horse wagon loaded with 4 cross-ties	800
1-horse wagon loaded with 4 cross-ties	800
2-horse wagon loaded with 2 crates of chickens	150
2-horse wagon loaded with 5 cases of eggs	500

	Pounds.
2-horse wagon loaded with $\frac{1}{8}$ cord of stove wood.....	500
2-horse wagon loaded with 3 cross-ties.....	600
2-horse wagon loaded with barbed wire.....	800
2-horse wagon loaded with $\frac{1}{4}$ cord of stove wood.....	1,000
2-horse wagon loaded with $\frac{1}{4}$ cord of stove wood.....	1,000
2-horse wagon loaded with $\frac{1}{4}$ cord of stove wood.....	1,000
2-horse wagon loaded with 6 cross-ties.....	1,200
2-horse wagon loaded with merchandise.....	1,400
2-horse wagon loaded with pine lumber, 500 feet.....	2,000
3-horse wagon loaded with 12 cross-ties.....	2,400
3-horse wagon loaded with 15 cross-ties.....	3,000
Average weight of load.....	1,097

An analysis of four of these cases gives the following interesting details:

	Pounds.
1-horse wagon loaded with 4 cross-ties.....	800
(8-mile haul, 1 day to make trip, 3.2 ton-miles, estimated cost per ton-mile, \$0.625.)	
3-horse wagon loaded with 15 cross-ties.....	3,000
(13-mile haul, 1 day for trip, 19.5 ton-miles, estimated cost per ton-mile, \$0.205.)	
3-horse wagon loaded with 12 cross-ties.....	2,400
(10-mile haul, 1 day for trip, 12 ton-miles, estimated cost per ton-mile, \$0.33.)	
2-horse wagon loaded with pine lumber, 500 feet.....	2,000
(10-mile haul, time from 7 a. m. to 3 p. m., 10 ton-miles, cost per ton-mile, \$0.30.)	

On the basis of \$2 per day for single teams, \$3 per day for double teams, and \$4 a day for three-horse teams, for the four cases in which complete information was secured, the average cost for the 44.7 ton-miles moved was 29 cents per ton-mile. For the entire 16 cases referred to the cost per ton-mile would be much higher, as most of them represented only partial loads. (See Pl. V, fig. 1.)

In the winter and spring months the average weight of load for a two-horse team was about 20 bushels of grain, or about 1,200 pounds. When the roads were dry, 40 bushels of grain, or 2,400 pounds, made an average load. On the basis of a 10-mile haul, and \$3 per day for man and team, the cost would be 25 cents per ton-mile on the roads when dry, 50 cents when the roads are wet and muddy, and at least 30 cents for the year around.

The 1912 inspection was made March 19, 20, and 21, after the road from Fredericksburg to Spotsylvania Court House, $11\frac{3}{4}$ miles, had been completed. The average load for a two-horse team on this road was now found to be 1,000 feet of lumber, or about 4,000 pounds. On the basis of a 10-mile haul, and \$3 per day for man and team, the cost was 15 cents per ton-mile.

It was noticed that many teamsters were accustomed to loading 1,000 feet or more of lumber on narrow-tired wagons, which resulted in considerable damage to the roads, especially in wet weather. To prevent this damage the county supervisors passed an ordinance limiting loads of lumber to 1,000 feet, or 4,000 pounds, on wide-tired vehicles, and to 600 feet on narrow-tired wagons. As a result of this ordinance most of the teamsters have provided themselves with wide-tired vehicles, 3-inch tires for 2-horse vehicles and 4 to 6 inch tires for 4-horse vehicles. Since the roads have been improved drivers frequently hitch two wagons together and use 4-horse teams, hauling 1,000 feet on each wagon if equipped with wide tires, or 600 feet on each wagon if equipped with narrow tires. On account of the ordinance limiting the weight of loads, it was difficult to secure from the drivers exact information on this subject. As a matter of fact, many of the teamsters hauled more than the law allows, and several of them have been indicted for violating the ordinance.

It was found that on the improved roads some wagons carried manure, hay, or merchandise on the return trip. For instance, on this inspection trip it was observed that one lumber team, on returning home $3\frac{1}{2}$ miles, carried $1\frac{1}{2}$ tons of manure. Another 2-horse lumber team returned with a 2,300-pound load, $3\frac{1}{2}$ miles. Still another team was seen making the 12-mile home trip with 1 ton of hay. Heavy hauling is now done on these roads all the year round, but before the roads were improved it was impossible to do heavy hauling at all at certain seasons of the year; the roads were simply impassable, except for light vehicles and those who traveled on horseback. Where teams are enabled to travel both ways loaded the cost per ton-mile is lowered about one-half.

The inspection made between April 2 and 12, 1913, showed that traffic conditions had further improved, and instances were repeatedly met with showing that the improved roads had materially bettered marketing conditions.

The character of products hauled, weight of loads, distance hauled, and cost per ton-mile of a portion of the traffic noted during the 1913 inspection is shown in Table 6.

TABLE 6.—*Hauling data for loads met on roads, Apr. 2 to 12, 1913.*

Vehicle and load.	Weight.	Distance hauled.	Ton-miles.	Cost for trip.	Cost per ton-mile.
	<i>Tons.</i>	<i>Miles.</i>			<i>Cents.</i>
Double team:					
20 ties.....	2.00	8	16.0	\$2.00	12.5
1,000 feet lumber.....	2.00	8	16.0	2.00	12.5
21 white-oak ties.....	2.10	11	23.1	3.00	13.0
1,000 feet lumber.....	2.00	6	12.0	1.50	12.5
1,300 feet lumber.....	2.60	11	28.6	3.00	10.5
20 white-oak ties.....	2.00				
900 feet lumber.....	1.80	7	12.6	1.50	11.9
1,500 feet lumber.....	3.00	11	33.0	3.00	9.1
1,100 feet lumber.....	2.20	8	17.6	2.00	11.3
1,000 feet lumber.....	2.00				
Do.....	2.00				
Do.....	2.00	15	30.0	3.50	11.7
11 ties.....	1.10				
$\frac{3}{4}$ cord wood.....	1.50				
13 ties.....	1.30	12	15.6	3.00	19.2
1,000 feet lumber.....	2.00	12	24.0	2.50	10.4
4-horse team:					
1,500 feet lumber.....	3.00				
2,000 feet lumber.....	4.00				
Do.....	4.00	10	40.0	3.00	7.5
Single team:					
5 ties.....	0.50				
6 ties.....	0.60				
Do.....	0.60				
400 feet lumber.....	0.80				
500 feet lumber.....	1.00	6	6.0	1.50	25.0
Average for 13 loads.....	2.15	9.6	20.6	2.423	11.76

¹ Teamsters get \$3.50 per 1,000 feet for this haul and make 1 trip a day.² Teamsters get \$2.50 per 1,000 feet and make 1 trip a day.³ On basis of $1\frac{1}{4}$ trips per day; round trips made in 7 hours.

Of the 13 cases for which complete information was obtained it appears that the average load for a 1-horse team was 1,400 pounds, for a 2-horse team 3,950 pounds, and for a 4-horse team 7,333 pounds; the average distance hauled was 9.6 miles, thus making the average cost 11.7 cents per ton-mile.

The 1914 study made on February 9 and 10 showed that the improvement of the road from Partlows to Spotsylvania Court House had opened up a large territory from which lumber and ties could be profitably hauled through to Fredericksburg. In 1913 large quantities of ties and lumber were brought to Spotsylvania Court House from the surrounding country and there reloaded in bigger loads, from which point they were hauled to Fredericksburg with 2-horse teams. In 1914 this point of transfer was moved farther out on account of the improved road, which will increase the average haul for such products and reduce the cost of marketing.

The traffic encountered between 8.15 a. m. and 11 a. m. on February 10, 1914, on a trip from Fredericksburg to Spotsylvania Court House comprised 62 vehicles, 44 of which were loaded with lumber, ties, etc.; going to Fredericksburg. For 6 cases on which complete information was obtained the average load was 2.38 tons, the average distance was 12 miles, the average ton-miles for each team per day was 28.5, and the average cost per trip about \$3.50, making the average cost about \$0.12 per ton-mile. (See Pl. V. fig. 2.)

TRAFFIC CENSUS.

In order to verify and complete data as to the volume of traffic and the cost per ton-mile on the different roads, three traffic takers for Spotsylvania County were appointed in the early part of 1914. The census covered one week in March and July, respectively, including Sundays, two weeks in December, 1914, excluding Sundays, and one week in April, 1915, including Sunday.

The traffic area served by these roads covers practically the whole county, which contains 360,680 acres. There is some traffic from Caroline County, but this does not sensibly affect the total.

The results of these censuses are shown in Table 7, in which attention is called to the fact that the average haul includes the distance on both the improved and unimproved roads.

TABLE 7.—*Traffic census on three improved roads in Spotsylvania County, Va.*

Road.	Average teams per day.	Average loaded teams per day.	Average tons hauled per day. ¹	Average tons hauled per year.	Average haul. ²	Annual ton-miles.	Average cost per ton-mile.	Average motor vehicles per day.
Courthouse.....	217	79	190.4	59,460	<i>Miles.</i> 13.42	804,564	<i>Cents.</i> 13	26
Plank.....	155	45	103.4	32,266	8.5	281,796	15	16
Partlows, Mount Pleasant to Spotsylvania C. H.....	73	27	49.3	15,397	9.49	158,472	14	13

¹ Based on three 6-day censuses and one 12-day census.

² Distance includes both improved and unimproved roads.

Practically all tonnage shown for the Mount Pleasant Road also passes over the Courthouse Road on its way to the market or shipping point at Fredericksburg. From Table 7 it will be seen that the total annual traffic over the Courthouse and Plank Roads amounts to 91,726 tons net. It is estimated that the total traffic on the River Road is about one-fourth of the total tonnage on the other two roads, or 22,930 tons annually, which makes a total traffic passing over the bond-built roads of the county of 114,656 tons net.

In ascertaining the tonnage and the ton-mileage passing over the roads no computation was made of the motor-vehicle traffic, except a count of the number of motor cars, but it is worth while to mention that on a tonnage basis and at an average weight of 1.45 tons for a total of 18,980 cars passing over the roads in the year, with an average distance traveled of 9.8 miles, the automobile traffic represented 27,521 tons, or 271,511 ton-miles, a traffic equivalent to 29 per cent of the net ton-mileage of products hauled. Thus in a strictly rural county the motor traffic has already assumed striking proportions.

The total net ton-mileage on the bond-built roads, exclusive of automobile traffic, the approximate cost of moving this tonnage before

and after the roads were improved, and the estimated annual saving, are shown in Table 8.

TABLE 8.—*Annual ton mileage and total saving on basis of tonnage hauled after road improvement, for roads improved under the bond issue.*

Road.	Tons hauled per annum.	Estimated average haul on improved road.	Average annual ton-miles.	Average cost per ton-mile.		Total cost of hauling.		Estimated gross annual saving
				Before improvement.	After improvement.	Before improvement.	After improvement.	
		<i>Miles.</i>		<i>Cents.</i>	<i>Cents.</i>			
Courthouse.....	59,460	10.00	594,600	30	13	\$178,380.00	\$77,298.00	\$101,082.00
Plank.....	32,266	8.00	258,128	30	15	77,438.40	38,719.20	38,719.20
River.....	22,931	3.00	68,793	30	15	20,637.90	10,318.95	10,318.95
Total and average..	114,657	1 8.03	921,521	30	1 13.7	276,456.30	126,336.15	150,120.15

¹ Weighted average.

The total tonnage figures for the Courthouse and Plank Roads are the same as those given in the traffic census table (Table 7), but the average haul given is for the improved roads only.

The saving in hauling costs appears to be about 16.3 cents per ton-mile, or a total of \$150,120.15 annually. If from this is deducted \$7,800, the present cost of maintenance, and \$8,650, the annual interest charges on the total bond issue, this would still leave a total annual saving of \$130,670.15, or an average net saving of 14.2 cents per ton-mile.

EFFECT OF ROAD IMPROVEMENT ON SCHOOLS.

The superintendent of schools reports a distinct increase in average attendance where the schools are located on improved roads. The percentage of attendance for certain schools located on road improved since 1910 is shown in Table 9.

TABLE 9.—*Percentage of attendance based upon total enrollment of rural schools in Spotsylvania County located on roads improved since 1910.*

Name of school.	School term.		Percentage of increase 1909-10 to 1913-14.
	1909-10	1913-14	
	<i>Per cent.</i>	<i>Per cent.</i>	
Lee's Hill.....	50	82	64
Leavell's.....	74	81	9
Courthouse.....	67	75	12
Massaponax.....	57	71	24
Salem.....	64	80	25
Colored school.....	41	67	63
Grange Hall, now Chancellor graded school ¹	47	81	72
Average.....	57	77	38

¹ This school, with two others, was consolidated into a modern 4-room building in 1912, and the figures above for 1913-14 are given for the Chancellor graded school at the Grange Hall site.

The figures given for the school term 1909-10 represent the percentage of attendance before the roads were improved and for 1913-14, since the roads were improved. The percentage of increase ranges from 9 to 72, and averages 38. The average attendance before the roads were improved was 57 per cent and in 1913-14, 77 per cent.

A consolidated school has also been established at Spotsylvania Court House, to take the place of the old school building located at that place (see Pl. VI). In 1912 there was a consolidation of several small one-room schools into one graded school on the Finchville road. It is evident that the improved roads have largely influenced the increased school attendance and the better educational facilities now offered to the country boys and girls of Spotsylvania County.

DINWIDDIE COUNTY.

Road improvement was begun in Dinwiddie County in 1908-9 through the construction of $9\frac{3}{4}$ miles of gravel road under the direction of the State highway department. On this road the county spent \$12,606.76 and the State furnished convicts to the extent of 7,919 convict days at an actual cost to the State of 72 cents per convict day. This improvement caused the people to realize the vast difference between a good road and a bad road, and as a result an election was held in 1909 and the four districts of the county were bonded to the amount of \$105,000.

In order to trace the results obtained through the expenditure of the bond issue, our economic investigations were begun in March, 1910, and subsequent studies were made in March, 1911, March, 1912, April, 1913, and February, 1914.

Dinwiddie County, it might be mentioned, is situated at the head of tidewater between the Appomattox and Nottoway Rivers, 22 miles south of Richmond, and has an area of 521 square miles, with a surface varying from gently rolling to level. Of the total area 79.8 per cent was in farms in 1910, but only 37.6 per cent of the farm area was improved. The principal crops are tobacco, peanuts, hay, grain, and vegetables. There are several large tracts of first and second growth timber and several sawmills are in operation.

HOW THE IMPROVEMENT WAS FINANCED.

Of the \$105,000 of bonds voted, \$30,000 was charged to Namozine District, \$22,500 to Rowanty District, \$27,500 to Darvills District, and \$25,000 to Sapony District, and these amounts were expended accordingly in the respective districts. The bonds all run 30 years, but are redeemable in 20 years. Of the first bonds sold in June, 1909, \$10,000 bear 5 per cent interest and \$30,000 6 per cent interest, the latter selling at a premium of \$3 on the hundred. The remaining \$65,000 were disposed of in 1910 and bear 6 per cent interest. If the

deferred serial method, with the first bonds falling due 6 years from date of issue and the last bonds 25 years from date of issue, had been adopted, the average annual outlay for interest and retirement of bonds would be \$8,044. Under the arrangement actually adopted it is planned that the sinking fund is to bear 4 per cent interest and the annual outlay, if adequate provision is made for sinking fund and interest to retire the bonds at the end of the twenty-fifth year, would be \$8,721.26. Thus the difference in favor of the serial method would be \$677.24 per annum, or a total of \$16,931, and the debt would be liquidated within the same period of years under either plan.

The total expenditure from the bond fund to September 30, 1915, was \$86,203.41, leaving a balance in the bond fund of \$18,296.59, which was deposited in banks at an interest rate of 4 per cent. It seems that the county sold most of the bonds before the money was actually needed, and accordingly the unexpended balance cost the taxpayers nearly 2 per cent interest over and above the rate allowed by the banks. If the bonds had been sold as needed, a saving of some thousands of dollars possibly might have been effected.

As indicating the relation which the tax burden for roads and for the bond issues bears to the taxes for other purposes, the details are given in Table 10.

TABLE 10.—*Detail of tax rates, 1910 and 1915.*

Purpose.	Rates in cents per \$100.	
	1910	1915
State tax.....	35	10
General county purposes.....	20	30
County schools.....	20	25
County roads.....	20	20
Road bonds.....		10
District schools.....	20	20
School bonds.....	5	5
Total.....	120	120

From this levy there was obtained in 1910 from the assessed valuation of \$4,428,584 a total revenue of about \$53,143, of which about \$8,857, or 16.6 per cent, was for county roads. No tax was levied in that year for the road bonds. The 1915 levy on the taxable valuation of \$5,985,140 produced \$71,861.28 for all purposes, of which \$11,970.28, or 16.6 per cent, was for county roads and \$5,985.14, or 8.3 per cent, was for interest and sinking fund on road bonds. This amount was insufficient to pay the interest on the road bonds, amounting to \$6,200, but the difference was made up by the 4 per cent obtained from the banks on cash balances of bonds sold. No provision has yet been made for the establishment of a sinking fund, and it must be evident that if the bonds are to be paid at maturity, such

provision should soon be made or else some relatively heavy taxes must be levied at no very distant date. If the necessary tax were levied from the outset only 15 cents on the hundred dollars would be required, but the longer this is delayed the greater the burden ultimately. While this county may make adequate provision in good time to care for its bonded indebtedness, the fact must not be overlooked that the sinking-fund method offers a temptation to keep putting off the day of reckoning, thus making necessary either the levying of heavy taxes at a time when the people have become accustomed to improved roads and a low rate, or, if the heavy taxes are not levied, the county must then face the necessity for refunding bonds. In this particular county the tax rate for the bonds was 15 cents on the hundred dollars in 1911, and the rate was reduced in 1912 to 10 cents and has remained at that figure since. The rate was cut down in order to provide revenue for a jail and for a steel index file without materially increasing the total rate for the county.

In connection with funds provided from the bond issues aid has been granted by the State in the form of convict labor, the State paying for guarding, clothing, feeding, and housing the convicts, while the county pays for their medical attention. One reason for the seemingly slow rate of expenditure of the bond issues by the county is the fact that all of the construction work is performed by the convict force, and the mileage completed each year is therefore limited by the constructive capacity of that force. From June, 1909, to September 30, 1915, the State had furnished 67,736.5 convict-labor days, which had cost the State an average of \$0.5468 per day, or about \$37,038.32. No money aid was granted by the State, as the State does not grant both convict and money aid to the same county during the same year. In measuring the results obtained for the given outlay it must be borne in mind that these results were not obtained by the bond issue alone, but that on the final showing the State will have paid nearly one-third of the cost, and, considering further that the convict labor is relatively cheaper than free labor, much of the credit for low cost of construction must go to the convict-labor plan rather than to other phases of the financing or management of the work.

HOW THE WORK WAS MANAGED.

The roads were built according to plans and specifications furnished by the State highway department and under the immediate direction of a superintendent selected by the State highway department and paid by the county from the bond-issue funds. The superintendent received a salary of from \$75 to \$100 per month, and reported both to the county road board, which has charge of all road work in the county, and to the State highway department. The road board con-

sists of 5 members, 1 from each district and 1 from the county at large. Previous to 1912 the members of this board were designated by the circuit court judge. Since that time the positions have been elective. The salary of the members is \$40 per annum each, except the secretary, who receives \$65 per annum. In addition to the salary members receive \$2 per day for inspection, not to exceed \$10 per annum for each district. The total salaries and expenses of the board are therefore about \$265 per annum.

There were 102.5 miles of road designated for improvement in the order of election issued by the judge of the circuit court. Namozine district was to have 30 miles; Rowanty district, 22.5 miles; Sapony district, 23 miles; and Darvills district, 27 miles. The work was begun on June 16, 1909, and is still in progress. The county has 524 miles of public road, of which 91.31 miles have been surfaced from the bond-issue funds, which, added to the 9.75 miles previously constructed, make 101.06 miles, or 19.3 per cent of the total mileage surfaced. (Pl. VIII.) Of the 91.31 miles, 81.1 miles were constructed with the aid of State convicts and 10.2 miles without convicts. The 81.1 miles cost \$68,490.72 in cash and 67,736.5 convict days. The cost of guarding, clothing, and food for convicts was paid by the State at an average of \$0.5468 per convict working day, or a total of \$37,038.32. The actual cost to the county was therefore \$844 per mile, and, including convict labor, the average cost was \$1,301.22 per mile. The total cost of the 10.2 miles built without convicts was \$17,712.69, or an average of \$1,736.53 per mile.

The roads were graded to an average width of 20 feet and were, for the most part, surfaced to a width of from 12 to 14 feet with top-soil, selected from near-by fields. The top-soil, which is a kind of natural sand-clay or gravel-clay mixture, consisted for the most part of clay naturally mixed with coarse sand or fine angular pebbles of disintegrated granite. This material is fairly well distributed throughout the county and in some cases was contributed free by abutting property owners. In other cases, however, it was purchased at 3 cents per cubic yard. Several sandy roads were treated with clay and several clay roads were treated with sand.

The county now has two surfaced roads radiating from Petersburg, extending entirely across the county. The Boydton Plank Road (Pl. VII, fig. 2, and Pl. X, fig. 2), 26.25 miles long, extends through the center of the county in a southwesterly direction along the Seaboard Air Line Railroad to the Brunswick County line. The Cox Road (Pl. IX, fig. 2), 32 miles long, extends through the northern part of the county in a westerly direction along the Norfolk & Western Railroad to the Nottoway County line. The Halifax Road has been improved for 3 miles south of Petersburg. The Stage Road has been improved for about 8 miles from the Nottoway River in a north-

easterly direction. The White Oak Road, about 15 miles of which has been improved, opens up the territory lying between the Cox Road and the Boydton Plank Road. This road is to be finished to the county line on the Nottoway River.

HOW THE ROADS ARE MAINTAINED.

The roads have not been systematically maintained, and while many sections are in excellent condition, other sections showed signs of wear and disintegration at the time of the 1915 inspection.

The condition of some of the roads before and after improvement is shown by the accompanying photographs. (Pls. VII and IX.) When the first inspection was made, during the latter part of March, 1910, the roads were practically impassable. The first year after construction the roads were more or less soft, but after the surplus clay had been leached out they became fairly hard and firm, even in wet weather.

The county road fund amounted to about \$12,000 in 1915, of which one-half is devoted to permanent work and one-half to maintenance. Six thousand dollars spread out over the whole mileage of the county amounts to only about \$11 per mile for maintenance, which is entirely inadequate. This work is carried on under the general direction of the county road board and under the immediate direction of the county superintendent of roads. The maintenance work is done by three small gangs of 5 or 6 men each, and a total of 6 mules for the three gangs. These gangs are principally engaged in cleaning out ditches, dragging, and patch work.

EFFECT OF ROAD IMPROVEMENT ON LAND VALUES.

The following table shows the assessed valuation of real and personal property and public service corporations for 1905, 1910, and 1915, exclusive of Petersburg, which is not assessed for improvements outside of its corporate limits. Property is assessed at about one-third of its cash value. According to law it should be assessed at its "fair market value."

TABLE 11.—*Detail of assessed valuation 1905, 1910, and 1915.*

Year.	Real estate.	Personal property.	Mineral lands.	Public service corporations.	Total.
1905.....	\$1,652,881	\$484,829	.....	\$1,091,523	\$3,229,233
1910.....	2,071,249	757,955	\$39,160	1,560,220	4,428,584
1915.....	2,855,343	1,063,820	.....	2,065,977	5,985,140

¹ Including tangible and intangible personal property and money as assessed under new tax law.

It will be seen from Table 11 that while the assessed values of real estate increased 25.3 per cent from 1905 to 1910, before the roads were improved, it increased 37.8 per cent from 1910 to 1915, the period which covers the improvement of the roads. In making the assessments for 1915 the assessors established a general rule of assessing all lands on the improved roads at a higher rate than those farther back; in fact, three zones were established on which land assessments were based. The first zone included all land abutting on or immediately contiguous to the improved roads; the second zone included all lands within easy hauling distance of the improved roads; and the third zone included all other land. The lands in the first zone were assessed at the highest rate, those in the second zone at about one-third less, and those in the third zone at about one-half of the first zone. By this arrangement those who own land on or near the improved roads and who receive the greatest benefit from them pay relatively more taxes than those who live on the unimproved roads.

That the increase in assessed value does not constitute a fictitious value, but an actual increase in value, is borne out by the records of sales. The actual value or selling price of land has greatly increased since 1909. This is attributed largely to the saving in cost of hauling and to the easier access of farms to markets and shipping points. The average value of 43 farms sold or offered for sale from 1909 to 1914 ranged from \$8.38 to \$43.74 per acre before the roads were built and from \$24.70 to \$73.60 per acre after the roads were improved. Our investigations brought out the fact that the farther away from town on the improved roads the land lies the greater the percentage of increase in value. Within 5 miles the percentage of increase was only 68.3; from 5 to 10 miles out the percentage of increase was 96.7, and from 10 to 24 miles out of Petersburg the percentage of increase averaged 194.9. Details regarding the 43 tracts above referred to are given in Table 12.

TABLE 12.—*Increase in land values.*

Number of cases considered.	Number of miles from Petersburg.	Old value per acre.	New value per acre.	Increase per acre.	Per cent of increase.
5	5 and less.	\$43.74	\$73.60	\$29.86	68.3
22	5 to 10	15.25	30.00	14.75	96.7
16	10 to 24	8.38	24.70	16.32	194.9

EFFECT OF ROAD IMPROVEMENT ON TRAFFIC.

The dairy and truck industries were profitably carried on before the roads were improved for a distance of only about 3 miles out from Petersburg, the principal market town. Petersburg is located

in the northeastern corner of the county, and considering it as the center of a traffic area, bounded by a circle with a radius of approximately 3 miles and a total area of approximately 28 miles, the portion of the area in Dinwiddie County, comprising one-fourth of the total, would be about 7 square miles. After the roads were improved it was practicable to conduct dairy and truck industries for a distance of 6 or 7 miles from Petersburg, and thus the radius was lengthened to 7 miles and that portion of the traffic area located in Dinwiddie County was increased to a total of 38.4 square miles, or an increase over the original traffic area of 31.4 square miles.

In arriving at the total tonnage hauled on the improved roads, it was ascertained that about 232,000 bushels of peanuts are produced annually in the county, and about 70 per cent of the crop is hauled to Petersburg by wagon, an average distance of about 10 miles. There are also produced in the county about 3,368,000 pounds of tobacco a year, of which about 80 per cent is hauled to Petersburg by wagon, an average distance of about 15 miles. These two crops require considerable fertilizer, which is hauled from Petersburg to the farm. As an indication of the volume of traffic it may be mentioned that the Atlantic Coast Line Railroad at Petersburg handled outgoing shipments in 1911 amounting to 25,364 tons, and it is estimated that this railroad carried about one-third of the incoming and outgoing shipments at Petersburg. Not more than one-half of the incoming and outgoing shipments at this point, however, pass over the improved roads of Dinwiddie County, as the other half originates in or is consigned to Petersburg and to the adjacent counties of Chesterfield and Prince George. It is estimated that in addition to the traffic centering at Petersburg, about 60,000 tons of miscellaneous and forest products are hauled to way stations over the improved roads for an average distance of about 5 miles.

In order to obtain further data on which to estimate the total annual traffic passing over the bond-built roads to the market or shipping point at Petersburg, four traffic censuses were taken on the Halifax and Cox Roads, covering a period of one year. Practically all the hauling from Dinwiddie County to Petersburg concentrates on these two roads within 2 miles from town. The census on the Cox Road was obtained about $1\frac{3}{4}$ miles from Petersburg and on the Halifax road about 1 mile from Petersburg. The census periods included a week in March, a week in July, two weeks in December, 1914, and a week in April, 1915. The weekly census included Sundays, and the two weeks' census excluded Sundays. Table 13 is based on the results of these censuses.

TABLE 13.—*Traffic census.*

Name of road.	Average number of teams daily.	Average number of loads daily.	Average tons hauled per day.	Average tons hauled per year.	Average length of haul. ¹	Annual ton-miles.	Average of all motor vehicles daily.
Halifax.....	148	70	48.14	15,002.6	² 10	150,026	70
Cox.....	240	137	156.46	48,813.4	² 18.3	895,343	72
Totals for Cox and Halifax Roads.....	388	207	204.6	63,815.0	² 16.4	1,045,369	142

¹ Average haul includes unimproved roads.² Weighted average.

From Table 13 it will be seen that the total traffic on the Cox and Halifax Roads is estimated at 63,815 tons, that the average haul for the two roads is 16.4 miles, and that the average annual ton-miles is 1,045,369. With the 60,000 tons of miscellaneous and forest products hauled to way stations over bond-built roads an average distance of about 5 miles, or a total of 300,000 ton-miles, the estimated total traffic for the county is 1,345,369 ton-miles per annum. The traffic area for the improved roads includes about 80 per cent of the land area of the county, or about 266,752 acres. The tonnage produced and hauled over the roads, therefore, amounts to a little over one-fourth of a ton to the acre.

The average haul on the bond-built portion of the Halifax Road is 3 miles, which for 15,002 tons makes 45,006 ton-miles, and on the Cox Road about 10 miles, which for 48,813 tons makes 488,130 ton-miles. By adding the 300,000 ton-miles of forest and miscellaneous products hauled over the bond-built roads to local shipping stations, a grand total traffic for the bond-built roads of 833,136 ton-miles is secured.

In ascertaining the tonnage and ton-mileage for the improved roads, no computation was made of the motor traffic, except to count the number of motor vehicles, which averaged 142 per day, but it may be of interest to note in this connection that on a tonnage basis, assuming an average weight of 1.45 tons, and an average number of 51,830 motor vehicles passing over the roads in a year an average distance of 6.2 miles, the automobile traffic represents 75,155 tons, or 465,952 ton-miles, while in number of vehicles it would represent 27 per cent of the annual total of all vehicles.

ESTIMATED ANNUAL SAVING ON HAULING COST.

The average load for a double team on the old roads was about 2,000 pounds, and on the new roads about 3,200 pounds, although much larger loads were by no means uncommon. (Pl. X, fig. 1.) The average haul for a double team on the old roads was about 10 miles, and on the new roads about 12.5 miles. The average cost of

team and driver was about \$3 per day. On this basis the cost of hauling per ton-mile on the old roads was approximately \$0.30 and on the new roads \$0.15. A saving of \$0.15 per ton-mile on 833,136 annual ton-miles amounts to \$124,970, which would be more than sufficient to retire the bonds in one year.

EFFECT OF ROAD IMPROVEMENT ON SCHOOLS.

One of the most important results attendant upon the improvement of the public roads in Dinwiddie County was the increase in attendance at the schools located on the improved roads. It was ascertained that during the school year 1912-13 the average attendance at 13 schools on the improved roads was 63.4 per cent of the total enrollment, and that the average attendance at all other rural schools in the county for the same year was 56 per cent. If the improved roads serve no other purpose than to equip with an adequate primary education 7 or 8 additional children each year out of each 100 enrolled the building of the roads would be justified.

Not only was the county school system affected through increased attendance, but also through the erection of larger school buildings (see Pl. XI, fig. 1) and the consolidation of small schools, while a particularly striking feature of the present school system is the transportation of the children to and from school. In 1914 several school wagons were in use, at an expense of about \$306 per annum for the operation of each wagon with a capacity of 20 passengers. (See Pl. XI, fig. 2.) About one-eighth of the children who attend school at Petersburg live in the surrounding country districts, some of them as far as 6 or 8 miles from town.

LEE COUNTY, VA.

Road improvement began in Lee County in 1908 through the construction of a road between Jonesville and Ben Hur, a distance of 5.6 miles. This, the first improved road in the county, was completed in 1910. The work was carried on under the direction of a resident engineer from the State highway department, labor was performed by State convicts, and the funds were raised by private subscription. The average cost of the road was \$4,203.68 per mile. Convict labor was furnished by the State to the extent of 10,035 convict working days, at a cost of 67 cents per day. The road was graded to a width of 30 feet, surfaced with macadam to a width of 12 feet, and a thickness of 6 to 7 inches consolidated.

The road served as a most successful object lesson to the people of the county, and the result was the voting of \$364,000 of bonds on November 29, 1910, for the purpose of improving approximately 165.5 miles of road.

The county is located in the extreme southwestern corner of the State, at the eastern base of the Cumberland Mountains, and has an area of 433 square miles. The topography varies from gently rolling to mountainous. The county is well watered by mountain streams and the soil is very fertile. About half of the area of the county is in cultivation and produces good crops of wheat, oats, corn, rye, potatoes, sorghum cane, hay, fruits, etc. Much of the land formerly devoted to the production of grain has, in recent years, been converted into grazing land, and cattle are now fattened for export on the blue-grass pastures without grain feeding. There are several tracts of standing timber.

The population in 1910 was 23,840. There are no cities or large towns in the county, and the county seat, Jonesville, is 5.6 miles from Ben Hur, the nearest railroad station.

As the bonds were voted late in 1910, the economic studies were begun in March, 1911, and continued in March, 1912, May, 1913, and May, 1914.

HOW THE IMPROVEMENT WAS FINANCED.

The bonds were issued by districts as follows:

Rose Hill district.....	\$65,000
Jonesville district.....	89,000
Rocky Station district.....	100,000
Yokum Station district.....	110,000
Total.....	364,000

As the bond election failed to carry in White Shoals district, no bonds were chargeable to that district. The bonds were dated January 2, 1911, carried $5\frac{1}{2}$ per cent interest, and were sold at a premium of 2 per cent, which amounted to \$7,280. The deferred serial method was followed, and the bonds were made payable as follows: January 1, 1916, \$14,000; January 1, 1917, and thereafter to January 1, 1930, \$15,000; January 1, 1931, to January 1, 1937, \$20,000. An annual tax levy to pay interest on the bonds and retire \$14,000 on January 1, 1916, should raise \$114,100 during 1911 to 1915, inclusive, or an average of \$22,820 per annum. Thereafter to pay interest and \$15,000 each year there would be required an average of \$28,887.50 per annum to January 1, 1930, and an average of \$24,400 per annum after that date for seven annual payments of \$20,000 each and interest. An examination of the steps already taken for the payment of interest and principal shows that the \$14,000 due January 1, 1916, has been paid and that the present rate of taxation appears to be sufficient to pay interest and the annual payments on principal as they become due. In 1913 the rates for these purposes were 65 cents in Rose Hill, Rocky Station, and Yokum Station districts, and 75 cents in Jonesville district, and produced about \$28,200.

In 1915 the rates were 75 cents in Rose Hill, 90 cents in Jonesville, 80 cents in Rocky Station, and 60 cents in Yokum Station, and produced about \$37,000. This is about \$10,000 per annum more than is needed for the first issue of \$364,000, but will be required to pay interest and create a sinking fund for the \$91,000 sinking-fund bonds subsequently issued.

While it is true, therefore, that the county adopted the most approved method of financing its road improvement so far as the first issue is concerned, it seems that it will have to carry a rather heavy tax burden. Applying this, however, to an individual case, it may be stated that a man owning a \$5,000 farm assessed at \$2,000, a fair example of the prevailing practice, would pay, on the basis of the 1915 rate of \$1.96 for all purposes, State, county, and road bonds, a total of \$39.20, of which 61 cents of the rate, or \$12.20 total, would apply to the road bonds.

In 1913 additional 5 per cent bonds, to the extent of \$60,000 for Rocky Station District and \$16,000 for Rose Hill District, were issued on the sinking-fund basis, bearing interest at 5 per cent. In the fall of 1915 Rose Hill District issued \$15,000 additional bonds. The sinking-fund method, as has been pointed out elsewhere in this bulletin, invariably proves more expensive than the serial method, except in those very rare cases where the sinking fund yields as large interest return as the interest payable on the bonds. The total of all bonds issued by the county was \$455,000, which, with premiums, yielded a total of \$464,560. This is the only bonded indebtedness of the county except \$11,000 of short-term bonds for two high schools. A striking illustration of the disadvantage incident to the issuance of bonds by districts rather than by counties is brought out by the experience of Lee County. White Shoals District, in which no bonds were issued (see Pl. XIII), extends entirely across the county, separating the improved roads of Rose Hill District, located in the southwest corner of the county, from the improved roads in the other parts of the county, thus imposing considerable inconvenience on other neighborhoods of the county, whereas if the county as a whole were handling the project the improvement could be systematically conducted. It is explained that the opposition in White Shoals District to the voting of bonds is due to the fact that convicts are not yet available for work in that district and that as soon as such aid is available the district will probably take up the work.

A comparison of taxation between the years 1910 and 1915 reveals the fact that while the total tax rate for all county purposes in 1910 averaged \$1.05, or, including the State tax, \$1.40, the rate had increased in 1915 to an average of \$1.86 for all county purposes and \$1.96 for all county and State purposes, a total tax-rate increase of 40 per cent, while the 61-cent average for road bonds was an entirely

new item in 1915. The county roads, the district roads, and the road bonds jointly required \$1.11, or 59.7 per cent of the county rate, or 56.6 per cent of the total for all purposes. This average rate for road bonds is somewhat misleading, as the individual rates range from a minimum of 60 cents in Yokum District to a maximum of 90 cents for Jonesville District. It may convey a more accurate conception of the situation, therefore, if the statement is made that the taxpayer in Jonesville District pays a total of \$2.25 on the hundred dollars of valuation for all purposes, of which 40 per cent is for the road bonds, this being the highest tax rate in the county. The reduction in the State tax for 1915 to 10 cents is partially offset by other forms of State tax on railroads, on cash in banks, on notes, bonds, and certain other intangible property. There was obtained from the assessed valuation of \$4,689,205 in 1910 about \$65,600, while from the assessed valuation of \$4,973,457 in 1915 there was obtained about \$97,500. Thus in spite of the improvement in the roads very little increase in the assessed valuation took place, and only by a marked increase of the tax rate was it possible to produce adequate revenue. This county, therefore, affords a striking exception to the general rule that improved roads bring about increase in assessed valuations.

HOW THE WORK WAS MANAGED.

The routes were selected and the number of miles to be improved and the amount to be expended determined without first obtaining engineering inspection and advice. This may account for the fact that the mileage of roads set forth in the order of election was greater than could be improved with the funds derived from the bond issue. This discrepancy between promise and fulfillment caused a considerable amount of dissatisfaction, and the experience of this county demonstrates the necessity for obtaining competent engineering advice before launching upon extensive road improvement. As pointed out elsewhere in this bulletin, legislation has recently been enacted in Virginia requiring inspection and preliminary estimates by the State highway department before bond elections can be held.

The general scheme of improvement was to construct two main roads extending through the county, with branch roads from the farming communities, but as White Shoals District failed to vote in favor of the bonds it was not possible to carry out the plan for two main roads. Less than 60 per cent of the roads originally provided for in the order of election have been improved. One road 20 miles in length, from Rose Hill to Cumberland Gap, and another road 8 miles in length, from Ben Hur to St. Charles, have been graded and macadamized. Three other roads, aggregating $22\frac{1}{2}$ miles in length, have been graded. A number of short sections in various parts of

the county have been improved by grading or have been graded and macadamized. Several of these short sections do not connect with other improved roads, and this fact, together with the failure of White Shoals District to vote the bonds, gives the county a rather disconnected system of roads, as shown by the map (Pl. XIII). Examples of contrasts on the Powells Valley roads are shown in Plate XV.

The roads were constructed according to plans and specifications furnished by the State highway department, and this work, as well as the supervision and inspection of construction, was performed by a county engineer selected by the State highway department. His salary of \$2,000, however, was paid by the county out of the funds derived from the bond issues. All contracts were let by the State highway department and the county board of supervisors, acting jointly.

The board of supervisors consists of five members—one for each district. They are selected by the people for terms of 4 years, and receive \$4 per diem for time actually employed, not to exceed 20 days per annum. There is one road superintendent in each district, appointed by the board of county supervisors. The road superintendents have charge of repairs and maintenance, and receive about \$100 per annum each. In the case of new construction, special superintendents are appointed, and receive from \$2.50 to \$3 per day.

According to information obtained from the State highway department, it is estimated that there are about 450 miles of road in the county, of which 39.26 miles, or 8.7 per cent, were graded and macadamized under the bond issue to October 1, 1915. In addition to this there were 60.19 miles graded but not macadamized, making a total of 99.45 miles, or about 22 per cent, graded and partly macadamized under the bond issue, with State aid in certain cases in the form of convict labor. Of the total mileage improved, 69.70 miles were constructed entirely out of bond-issue funds, but under the plan of State aid in effect in Virginia the county will ultimately be reimbursed to the extent of one-half of the cost of these roads. In building 29.75 miles, a total of 39,953.75 convict-labor days were contributed by the State at an average cost of 53 cents per day, or a total of \$21,175.48. The cash expenditure by the county on these roads was \$75,149.24, thus making the average cost of the convict-built roads \$3,237.79 per mile. Of the roads built with free labor, 16.63 miles were macadamized, and of the roads built with convict labor 22.63 miles were macadamized, but unfortunately no segregation is available of detailed cost of the macadamized roads and those which were merely graded. However, as an indication of these relative costs, it was ascertained that 10.5 miles graded and mac-

adamized under the money-aid plan cost an average of \$6,303.52 per mile, and that 47.25 miles graded but not macadamized cost \$3,248.83 per mile. On this basis the grading cost about 52 per cent and the macadam about 48 per cent. The transformation wrought by the new construction is strikingly shown in Plates XII and XIV.

HOW THE ROADS ARE MAINTAINED.

The improved roads of Lee County are not systematically maintained, and they are beginning to show signs of wear. A little work is done now and then in cleaning out ditches and opening up culverts under the direction of the district road superintendents. A 3-mile section of the road from Ben Hur to Jonesville was resurfaced in 1914 at a cost of \$2,500, paid from the bond-issue fund. This road was scarified and resurfaced with No. 2 stone and screenings, sprinkled and rolled down, and is now in very good condition. The balance of the road is badly worn and should be resurfaced as soon as possible. This is the only extensive repair work that has been done.

EFFECT OF ROAD IMPROVEMENT ON LAND VALUES.

Since changes in assessed valuation between 1910 and 1915, as pointed out elsewhere in this chapter, have been comparatively slight, it would appear, if such a standard indication were accepted, that the improved roads have not produced greater property values in the county. Personal inspection and inquiry in 1911, however, relating to 32 distinct farms, indicated an average value on the roads selected for improvement of \$40 per acre, while the lands along the cross-country roads averaged about \$25 per acre. Lands along the Ben Hur-Jonesville road, the only one improved up to that time, averaged about \$100 per acre, and it was ascertained that the average before the improvement was about \$25 to \$35 per acre.

In the 1913 study it was found that the average value of seven tracts of land selected at random on the improved roads, containing a total of 1,289 acres, was \$75 per acre, showing an increase in the two years preceding of about 80 per cent. One case deserves special mention as illustrating the effect of road improvement on land values. A tract containing 109 acres on the road between Ben Hur and Jonesville was sold before that road was improved for \$4,500, but the purchaser failed to take the land, claiming that the price was exorbitant. This same land sold in 1911, after the road was finished, for \$9,000, a gain of 100 per cent over the supposed exorbitant price.

TABLE 14.—*Values or sale price per acre.*

1911, before improve- ment.	1912, after improve- ment.	1911, before improve- ment.	1912, after improve- ment.
\$50	\$80	\$30	\$40
50	80	30	40
20	42	40	75
30	50		
20	40	Av. 33	56

Table 14 shows the approximate land values of eight tracts in the Powell Valley along the roads before and after improvement and that these properties increased about \$23 per acre, or about 70 per cent. If all of the improved farm land in the county within one-half mile of the improved roads increased in value at the same rate as the Powell Valley lands above referred to, the total increase would amount to \$860,940.

The foregoing examples, showing that there has been a decided increase in the value of lands along the improved roads, are in conflict with the record of assessed valuation.

EFFECT OF ROAD IMPROVEMENT ON TRAFFIC.

This county has an excellent home market at the various mining camps in the northern section of the county and in the adjacent county of Wise, but does not begin to supply the demands of those markets.

The traffic on the road connecting Jonesville, the county seat, with Ben Hur, its railroad point, is about the heaviest in the county, and represents about nine-tenths of the total freight receipts for shipment over the Louisville & Nashville Railroad at Ben Hur. It consists principally of coal and supplies hauled from the railroad station, and timber and other forest products hauled to the station for shipment.

The Tri-State Road, which extends from Cumberland Gap toward Jonesville through Rose Hill, also has considerable traffic. The hauling consists principally of foodstuffs from farms in the fertile Powell Valley to the market in Cumberland Gap and Middlesboro, Ky. The macadamizing of this road has opened up a large area of the Powell Valley to the market in Middlesboro. Since this road was completed there has been an increase of 25 per cent in the number of buggies sold by the wagon factory in Cumberland Gap and automobiles are being introduced into this section, which shows that the people are finding the improved roads of social as well as commercial benefit.

The road which connects Pennington Gap, the principal town of the county, with the mining section at St. Charles is another one of the principally traveled roads. Since the improvement several

hucksters in the county have established regular routes through the farming sections and buy up chickens, eggs, butter, and other products. These products are sold in the mining camps or hauled to the railroad stations. In this way the farmers receive cash for many perishable products which would otherwise be a total loss.

The improvement of the roads has brought about the shipment of large quantities of tanbark, extract wood, and pulp wood hitherto unprofitable. The teamsters in hauling lumber to Jonesville over 4 and 5 miles of earth roads, then on to Ben Hur over the macadam road, can only haul a small load into Jonesville, return for a second load, to which the first is added on reaching Jonesville, and then haul both in one load over the improved road to Ben Hur. In hauling coal from Ben Hur, two wagons are fastened together and drawn by one team to the end of the improved road, then uncoupled and hauled separately to their destination over the earth roads.

There are 97 miles of railroad in the county, and as a basis for ascertaining the tonnage hauled over the public roads, the freight shipments on the Louisville & Nashville Railroad at 11 stations in the county were ascertained in 1914 to be 49,733.23 tons of outgoing freight and 16,211.37 tons of incoming freight, exclusive of coal and iron ore, which do not pass over the public roads. From the data thus obtained and from a study of the traffic areas served by the roads, supplemented by actual observations of traffic, it has been estimated that the annual traffic, not including live stock, on the roads of the county in 1914 was as shown in Table 15.

TABLE 15.

	Tons.
Forest products.....	28, 000
Farm and miscellaneous products hauled to the railroad station and mining districts.....	25, 565
Feed, fertilizer, coal, groceries, and miscellaneous products.....	20, 630
Total.....	74, 295

Of the total tonnage it is estimated that approximately 80 per cent, or 59,436 tons, are hauled over the improved roads an average distance of 5 miles, thus making the total annual ton-mileage on the improved road system 297,180 ton-miles.

From numerous observations made in 1911, it was found that the average load for a two-horse team before the roads were improved was about 2,000 pounds in the summer and fall and about 800 to 1,000 pounds during the winter and spring, with an average throughout the year of about 1,500 pounds. Most of the hauling was done in the fall, so as to avoid bad roads during the winter and spring.

As compared with the average load on the old road of 1,500 pounds, the average on the improved road is about 4,000 pounds. The value

of a two-horse team and driver has increased from \$3 to \$3.50 per day in the past few years, due to the increased cost of feed.

Lumber is hauled into Pennington Gap 7 miles along the Dryden Road, 700 feet b. m. to the load. This road is now graded and about 1 mile macadamized. Two trips a day are now made by teamsters, who receive \$3 per 1,000 feet b. m., which is at the rate of 17 cents per ton-mile.

Hauling costs on the old roads varied all the way from 40 to 80 cents per ton-mile. The average cost per ton-mile for the cases under observation was 25 cents on macadam, 40 cents on graded roads, and 55 cents on the old roads. The saving is 30 cents on macadam and 15 cents on graded roads, and an average of about 20 cents per ton-mile. The total annual saving by reason of the improved roads would, therefore, be about \$59,400.

An implement dealer at Jonesville reports that he gave \$400 toward the building of the Ben Hur-Jonesville road four years ago and that he is now saving that amount each year by the reduced cost of hauling freight from Ben Hur. He paid for hauling freight from 15 to 20 cents per hundredweight for a 5-mile haul over the old road, which equals from 60 to 80 cents per ton-mile; on the improved road, from 8 to 10 cents per hundredweight for a 5-mile haul, which equals from 32 to 40 cents per ton-mile. For hauling coal, 10 cents per bushel of 80 pounds for a 5-mile haul on the old road, which equals 50 cents per ton-mile; on the improved road he paid 5 cents per bushel of 80 pounds for a 5-mile haul, which equals 25 cents per ton-mile.

WISE COUNTY, VA.

Road improvement in Wise County was begun in 1910 through the construction of 4.6 miles of macadam road under the supervision the State highway department. As was the case in other counties, the first example of good-road construction served as an object lesson and created a strong sentiment for comprehensive road improvement throughout the county. On November 22, 1910, a county bond issue of \$700,000 for grading and macadamizing 110 miles of road was carried by a vote of 2,156 for the bonds to 176 against them. Unfortunately, no preliminary surveys or engineering advice were obtained upon which to base the program of construction outlined in the order of election, and in consequence it was found, after the bonds had been voted and surveys for actual construction made, that the routes set forth in the order of election aggregated 125 miles instead of 110 miles, and that the cost of grading and macadamizing this mileage would amount to more than \$1,000,000 instead of the \$700,000 which the people had voted. This naturally caused some dissatisfaction and required a change in policy. It was, therefore, decided to grade the whole mileage and build permanent drainage structures, utilizing

what was left of the bond issue to macadamize the most important roads.

Following the first bond issue, two of the districts, Gladesville and Richmond, voted \$130,000 each in order to macadamize the roads which had been graded and to build a few additional miles.

The economic conditions in Wise County are rather exceptional, as the chief industry is coal mining; and the mineral lands, coal and iron, constitute about half of the assessed valuation of the county. There are 34 coal-mining plants, employing in the aggregate about 9,000 men. Agriculture is not extensively practiced, and the products, which are principally corn, oats, hay, potatoes, and sorghum cane, are small in volume. Some orchard fruits are produced, and dairying and poultry raising are engaged in on a small scale. The county is well supplied with railroads, and as its principal output is from the mines, comparatively little tonnage is hauled over the public roads. The county, which has an area of 420 square miles, is quite mountainous, and the soil is not productive, except at the bottom of the narrow valleys along the streams. This rough topography causes road construction to be very expensive, on account of heavy grading. (See Pl. XVIII.) Moreover, a large portion of the surfacing material must be transported by rail or by long wagon haul. The mining interests are paying the larger part of the costs of the road system, and in judging of the returns to the county from an economic standpoint it should be borne in mind that while the value of the road system to agriculture is slight, the corresponding burden upon agricultural property, by reason of the help of the mining interests, is also comparatively light.

The economic studies in Wise County were made during the months of March, 1911, March, 1912, May, 1913, May, 1914, and a short study in October, 1915.

HOW THE IMPROVEMENT WAS FINANCED.

The issue of county bonds dated February 1, 1911, brought a premium of 2 per cent, while the two district bond issues dated March 1, 1913, were sold at par. Thus the total amount realized from the bond issues was \$974,000.

All the bonds bear interest at the rate of 5 per cent, and are issued for 30 years with options to retire at the end of 20 years. The law provides that a levy of not to exceed 90 cents on the hundred dollars shall be assessed for the purpose of paying interest and creating a sinking fund to retire the bonds. The present tax for this purpose is 45 cents for the \$700,000 county bond issue and 20 and 25 cents, respectively, for the district bonds in Richmond and Gladesville districts.

The board of county supervisors is authorized to create a sinking fund and to apply any part or all to the purchase of any of the bonds at any time. The county board is further authorized to lend upon real estate security, the loan not to exceed 50 per cent of the assessed value of such real estate, or deposit in bank at interest all accumulations of money to the credit of the sinking fund. No sinking funds have been so invested, as it is difficult to lend money on real estate on a 50 per cent assessment basis, and for that reason the board of supervisors expect to purchase and retire the bonds as fast as money accumulates in the sinking fund, provided the bonds are on the market at a price which would be advantageous to the county. This method would be somewhat similar to the deferred serial method.

It must be borne in mind, however, that the holders of the bonds might, up to the twentieth year, refuse to surrender them, and would thus force the sinking-fund method upon the county. This element of uncertainty is the weakness of the retirement method as contrasted with a regular deferred serial method.

On the basis of the 1915 assessment of \$13,500,000, the \$700,000 of county bonds could be paid off in 25 years by an average tax rate of 36.7 cents per hundred dollars to be devoted to payment of interest and retiring the bonds annually, and the total amount paid out would be about \$1,241,500 if \$35,000 of the bonds are purchased at par each year after the fifth year instead of establishing a sinking fund. Under the sinking-fund plan, with sinking fund bearing 3 per cent and running 25 years, the total cost would be \$1,354,988, or an average of \$54,199 per annum for interest and retirement. The total saving by paying off the bonds instead of accumulating sinking fund would be \$113,488. The tax rate for the sinking-fund plan would be 40 cents on the present valuation as compared with 35.7 cents for the deferred serial plan, or for buying up the bonds at par.

If the total bond issue of \$960,000 were retired the twenty-fifth year on the sinking-fund plan, with interest on sinking fund at 3 per cent, the total cost would be \$1,858,269. If the serial plan were adopted with the first payment, beginning on the sixth year, and the last payment the twenty-fifth year, the total cost would be \$1,704,000, thus showing a total saving by the deferred serial plan of \$154,269, as compared with the sinking-fund plan. Even if 4 per cent could be realized on the sinking fund, there would still be a saving of \$72,288.

The tax levies are fixed annually by the county board of supervisors, and in order to provide for the county bond issue the board levied a tax of 30 cents on the hundred dollars in 1910, but even with this additional burden the tax rate for local purposes was only 10 cents higher in 1910 than in 1905, as there was a reduction of 5 cents in the tax for general county purposes and a total elimination of the tax of 15 cents for district roads. Thus the total tax burdens

were \$1.30 in 1905 and \$1.40 in 1910. In 1915, however, the tax rate had risen very materially, as the total tax averaged \$1.65, in addition to which a district tax was levied in Richmond and Gladesville districts of 20 and 25 cents, respectively, for road bonds, so that in those two districts taxpayers were paying a total rate for all purposes, State, county, and district, of \$1.80 and \$1.90, respectively, of which the road bonds, the county roads, the district roads, and the district road bonds taxes formed 55.5 and 57.8 per cent, respectively. It is thus evident that the good roads carried with them a material tax burden. Although about 65 per cent of the taxes are paid by the public service and mining corporations, these organizations were in favor of the bond issues for road improvement. It seems quite probable that the highest point of taxation has, however, already been reached and that a slight reduction may be expected in the future. The 10-cent special county road levy for 1915 was to apply to the payment of an excess of about \$57,000 in the cost of the roads over and above the amount obtained from the bond issue. A 20-cent tax was levied for this purpose in 1914, and it is expected that this 1915 levy will be sufficient to retire all of the floating debts. Averaging the rates for all purposes over the entire county, it appears that while the average rate increased 25.7 per cent from 1910 to 1915 the receipts from taxation increased 55.3 per cent, or from a total of about \$154,600 in 1910 to a total of about \$240,100 in 1915. The road bonds required 33.8 per cent of all the receipts for local purposes in 1915.

AID GRANTED BY STATE.

Under the Virginia law the State pays one-half of the cost of all State-aid roads and provides that if the county issues bonds and pays more than 50 per cent of the cost it shall be entitled to receive an annual apportionment until the receipts from the State shall equal 50 per cent of the cost of improvements. Wise County is, therefore, entitled to receive from the State one-half of the money expended on this work, which half amounts to \$515,789. From 1910 to 1915, inclusive, the county received from the State \$40,904.

The State money aid is derived from an annual appropriation made by the General Assembly of Virginia and apportioned among the various counties on the basis of taxes paid by the counties to the State. The automobile-license money is derived from the State automobile-license fund and is apportioned among the various counties in the same manner as the State-aid money.¹

The funds derived from these sources may be used toward paying interest or retiring the bonds, for maintenance, or for construction

¹ An act passed in 1916 by the legislature provides for the use of the automobile funds for maintenance of State-aid roads.

of new roads. It is the present practice and intention of the county authorities to use it for the building of new roads and in the maintenance of roads already constructed.

HOW THE WORK WAS MANAGED.

From July, 1911, when the first contracts were let, to September 30, 1915, a total of \$1,031,578.54 was expended in the construction of the improved roads. With this amount 144.52 miles of road were graded, of which 78.47 miles were macadamized. Of the macadam roads, 24.34 miles were surfaced with bituminous material. There were also constructed 30 steel bridges and 95 concrete culverts. Of the first bond issue of \$700,000, about 76 per cent was spent for grading, 3 per cent for bridges, and 21 per cent for macadamizing. Nearly all of the two district bond issues, aggregating \$260,000, was spent for macadamizing roads previously graded. The cost of surface treatment of 24.34 miles of macadam roads amounted to \$9,758.82, or \$400.93 per mile. The roads were graded to a width of from 16 to 18 feet, while the macadam surface varied from 9 to 12 feet. A good contrast between the old and the new roads is shown in Plate XVI.

It is estimated that there are about 300 miles of public road in the county, of which 83.07 miles, or 27.6 per cent, have been macadamized. (See Plate XVII.) This includes 4.6 miles of State-aid macadam. In addition to this, 66.05 miles have been graded under the bond issue and 1.3 miles with local funds, making a total of 150.42 miles, or 48.6 per cent of the total, partially or wholly improved.

The State highway department furnished plans, specifications, and estimates for the roads and supervised the actual construction, but, as has been pointed out in connection with other county studies, the State highway department was not called in to make any examination and estimate before the bonds were voted, and this absence of competent advice was decidedly injurious to the county. The immediate supervision of the work was intrusted to a county engineer appointed by the board of supervisors with the approval of the State highway department. His salary of \$175 to \$200 per month was paid by the county out of the bond-issue funds.

The roads were built by contract awarded by the State highway commission and the county board of supervisors under the unit-price system, with the exception of some macadam surfacing under the district bond issues where the work was done by force account.

The regular road work of the county is carried on by the district road superintendents, under the general direction of the county board of supervisors. The board consists of four members—one for each district. They are elected by the people for 4-year terms and receive \$4 per day for time actually employed, not to exceed

30 days per annum. The district road superintendents, one for each district, are appointed by the board of county supervisors for terms of 2 years and receive \$3.50 per day for time actually employed. There are no toll roads.

HOW THE ROADS ARE MAINTAINED.

Very little has been done previous to the present season toward the maintenance of the roads improved, except to keep ditches and culverts open. The roads were beginning to show signs of wear and, in 1915, 24 miles were surface-treated with bituminous material and stone chips at a cost of about \$400 per mile, paid from bond-issue funds. About one-half gallon of bituminous material and 21 pounds of screenings were used to the square yard. The roads which were treated are the most heavily traveled roads of the county. This work was done by the district superintendents under the general direction of the board of county supervisors.

The use of bond issue funds for maintenance is exceedingly unwise as the debt outlives the temporary improvement by many years.

EFFECT OF ROAD IMPROVEMENT ON LAND VALUES.

A comparison of assessed valuations brings out the fact that in 1910, the year in which the bonds were voted, the assessed valuation was \$11,011,788 and that in 1915 it had increased to \$13,629,383, a gain of \$2,617,595, or 23.7 per cent. The mineral lands, which formed 43.6 per cent of the total value of all property in 1915, showed a decrease of 4 per cent in value, as some lands which were assessed as mineral lands in 1910 were assessed as nonmineral lands in 1915, and furthermore, the building of the improved roads would naturally have a comparatively slight effect upon the value of mineral lands, as the operation of the mines depends more upon railroad than public-road facilities. The nonmineral lands, however, increased nearly 31 per cent from 1910 to 1915. It is difficult to gauge the increase in actual values by assessed valuation figures, as the relation between assessed value and actual value varies from 20 to 90 per cent, and probably averages about 60 per cent of the actual value.

Personal investigation, however, as to sale values brought out some convincing evidence as to the effect of the improved roads upon sale values. Of the large number of individual cases considered, eight, selected as fairly representative, are presented in this chapter. The value of these eight farms located on improved roads in various parts of the county increased 61.9 per cent, or from an average of \$49.06 per acre before the roads were improved to \$79.44 after the roads were improved, and it is commonly accepted in the county that the increased value was due almost entirely to the road improvement.

A farm near Big Stone Gap, containing 100 acres, was valued in 1910 at \$70 an acre and in 1913 at \$100 per acre.

A farm 1 mile east of Coeburn, containing 100 acres, was valued at \$60 per acre in 1910, before the road was improved, and in 1913 at \$90 per acre.

A portion of a farm between Big Stone Gap and Minton, containing 30 acres, was sold in 1914, after the road was improved, for \$50 per acre. This whole farm was purchased in 1908 for \$10 per acre.

A tract between Coeburn and Norton, containing 12 acres, was purchased in 1910 for \$33 per acre, and was sold by the purchaser in 1914 for \$150 per acre.

A portion of a farm on the road from Wise to the Dickenson County line originally contained 80 acres, valued in 1911 at \$30 per acre, and was sold in 1912 for \$50 per acre.

On the same road, 35 of the 160 acres of a farm, valued at \$30 per acre in 1911, sold in 1912 for \$40 per acre.

A farm between Norton and Wise, containing 30 acres, was valued at \$25 per acre in 1911, and was sold in 1914 for \$33 per acre.

Another tract located on an improved road, and containing 100 acres, one-half of which is cultivated in grain and fruit, was valued at \$60 per acre in 1910, and had increased in value to \$100 per acre in 1913.

EFFECT OF ROAD IMPROVEMENT ON TRAFFIC.

As the principal exports of the county are coal and coke, for the transportation of which there is an exceptionally large railroad mileage in the county, the traffic conditions from the public-roads standpoint are not especially striking. The county does not raise enough vegetables for its own consumption, and probably 75 per cent of all the green truck used in the towns and mining camps is shipped in from outside the county. Not over 60,000 acres in the entire county are devoted to agricultural purposes. As nearly as can be ascertained, the tonnage hauled over the improved roads in 1915 was as shown in Table 16.

TABLE 16.

	Tons.
Farm products.....	10, 000
Forest products.....	32, 000
Fuel.....	4, 000
Fertilizers, groceries, etc.....	4, 000
Total.....	50, 000

The tonnage of farm products amounts to about 0.16 ton per acre for the 60,000 acres devoted to agriculture.

Based upon information secured from drivers of teams, it was found that the average load on the roads before improvement was

1,500 pounds, with an average haul of 4 miles. Estimating cost of driver and 2-horse team at \$3.50 per day, and that two trips were made per day, it follows that the cost per ton-mile was 57 cents. After the roads were improved, the average load for the whole improved road system, comprising not only macadam roads, but graded earth roads as well, was 2,500 pounds. This increase in load serves to decrease the hauling cost to 35 cents per ton-mile, but on the improved roads it is possible for a 2-horse team to make three trips of 4 miles each per day, which still further reduces the cost to about 23 cents per ton mile, a saving of 34 cents per ton mile, which, applied to the entire 200,000 ton-miles, would aggregate \$68,000 per annum. This computation is not intended to represent an actual saving of that amount of money to the people of the county, but is rather intended to afford a basis for estimating the loss of time and energy on the old roads. As indicating the individual benefits of lowered hauling costs, one teamster found that he would save \$1,500 in hauling 800,000 feet of lumber, as he would be able to haul 1,200 feet with each two-horse team on the new roads as compared with 800 feet on the old roads.

EFFECT OF ROAD IMPROVEMENT ON SCHOOLS AND SOCIAL CONDITIONS.

The principal advantage of the improved roads has so far been to facilitate travel from point to point and to better school and social conditions. (See Pl. XIX.) The postmaster at Big Stone Gap is authority for the statement that every family on his rural delivery routes has either built a new home or improved the old one since the roads were finished. The sanitary conditions in the country districts have improved, and many conveniences and comforts are now provided in farm homes which would have been considered luxuries when these homes were partly isolated by the bad roads.

The following information showing the relation of improved roads to the schools was furnished by James N. Hillman, the superintendent of schools of Wise County:

At least 40 per cent of the school population is in what is classed as strictly rural communities. Here the average daily attendance, as well as the enrollment, has increased by leaps and bounds since the building of our roads. For example, the enrollment for the year ending June 30, 1915, was more than 1,000 increase for the year over any preceding year. The average daily attendance increased 700, the greatest in the history of the county.

The past month (September, 1915), we enrolled in round numbers 9,000 pupils, out of a total school population of 11,000, and had an average daily attendance of more than 8,000, or about 90 per cent. This is the greatest in the history of the county, as the yearly average attendance heretofore has been between 60 and 70 per cent. I might add that we have a form of compulsory attendance in effect this year, which, no doubt, is responsible for some of the unusual increase in daily attendance.

We confidently expect our enrollment to reach 10,000 during the year. We also expect to see the average attendance close to 8,000,

Schools that had to close by reason of failure in attendance previous to the building of good roads now assist in supporting good consolidated schools, at which the attendance is splendid.

The 4-room school known as Maple Grove, in the Hurricane District, is one of these. It supplants three 1-room schools, each of which, without exception almost, failed every year to keep up its average. At present there are but two teachers in the consolidated school, but they have an enrollment of 64, with an attendance last month (September, 1915), of 59.

The Duncan Gap School, a 2-room building, supplanting two 1-room schools, is doing well, and would not have been possible but for good roads, in my opinion.

The above schools are in the heart of the *country*.

The percentage of population enrolled has increased from about 70 per cent during our bad roads to at least 90 per cent for the last year, before compulsory attendance was enforced, and will be better than that this year, I have no doubt.

It might be well to add, also, that a number of parents who own automobiles and who live in the country districts are now bringing their children into larger towns, that they may have the benefit of a strictly graded, well-manned high school. Before our good roads this was, of course, absolutely impossible.

FRANKLIN COUNTY, N. Y.

In 1910 Franklin County authorized the issue of \$500,000 in bonds with which to improve certain important roads designated as county roads. The county is located in the northeastern part of the State, extending from the St. Lawrence River to well within the Adirondack Mountains and comprising a land area of 1,678 square miles, or 1,073,920 acres, of which, in 1910, 18.6 per cent, or 199,824 acres, was improved farm land. The topography varies from comparatively level in the north to rolling in the central portion and mountainous in the south, with an average elevation above sea level of 155 feet in the north, 800 feet in the central portion, and 1,600 feet in the southern portion. Small rivers and creeks are numerous. The soil varies from dark vegetable clay loam to light sandy loam. During the winter snow generally covers the ground for a period of 3 to 4 months. The snow roads, when rolled or packed down, are very good, and loads weighing 2 tons or more are readily drawn with 2 horses. A large proportion of the forest products which pass over the public roads are hauled on sleds during the winter months.

The county is well provided with road-building material. There are numerous outcroppings of Adirondack gneiss in the southern part, of granite and sandstone in the central, and of dolomite and limestone in the northern part. Glacial deposits of granite and sandstone boulders and gravel are everywhere abundant and of excellent quality for road-building purposes.

There are no large cities within the county or in the immediate environment. Malone, the county seat and principal town, had a population in 1910 of 6,447. The population of the entire county was 45,717 in 1910.

The principal industries are dairying and lumbering. The chief crops are potatoes, hay, hops, barley, and corn fodder for silage. A considerable amount of maple sugar is also produced. Most of the milk and cream in Franklin County is hauled from the farms by the dairy companies.

SUMMER RESORTS AND TOURIST TRAVEL.

The southern half of Franklin County is in the heart of the Adirondacks and there are hundreds of beautiful lakes surrounded by camps, cottages, villas, and hotels. During the calendar year 1912 there were 371 automobiles registered in the county, of which 11 were commercial vehicles. During 1914 the registrations had increased to 823 pleasure cars and 30 commercial vehicles. This does not, however, represent the total number of motor vehicles using the roads of Franklin County, as the Adirondacks region is visited every summer and fall by thousands of tourists from all parts of the country.

The various hotels and summer resorts afford excellent markets for fruits, vegetables, poultry, and dairy products. There are no canning factories in the county, and as the soil and climatic conditions are well adapted to the growth of fruits and vegetables, it is believed that when all the main roads are improved there will be a good opportunity for developing this industry.

Three inspection trips were made through the county on the following dates: May, 1912, May, 1913, and May-June, 1914.

HIGHWAY CLASSIFICATION AND MAINTENANCE.

The roads selected for improvement under the bond issue by the county board of supervisors have an aggregate length of 135 miles, and in connection with the State and county highways will form a system connecting the principal towns, market centers, and summer resorts of the county. The total public-road mileage of the county aggregates 1,370 miles, of which 145 miles, designated as State and county highways, are being improved under the supervision of the State highway department. About 212 miles of town roads have been surfaced, so that when the contemplated work is completed the surfaced roads of the county will comprise 492 miles, or about 36 per cent of the total mileage. (See Pl. XXII.)

The roads, as planned at the time of the last inspection, are divided into four classes, and are paid for and maintained as follows:

State highways.—Seventy-five miles. Paid for wholly by the State from the \$100,000,000 bond issue. Maintained by State, under patrol-and-gang system, but towns contribute \$50 per mile per annum. Patrolmen receive \$3 per day and furnish their own teams.

County highways.—Seventy miles. Paid for partly by the State, partly by the county. The amount paid by the county is deter-

mined by taking 2 per cent of each thousand dollars of assessed valuation per mile of public road. The county's share shall in no case exceed 35 per cent of the cost of the improvement. County highways are maintained by the State in same manner as State highways, the towns paying \$50 per mile per annum.

County roads.—One hundred and thirty-four and six-tenths miles. Paid for entirely by the county, exclusive of the towns. The county roads are the ones which are built from the county bond issue. They are maintained by county, by day labor under patrol-and-gang system (see Pl. XXIV) the State paying 50 per cent.

Town highways.—One thousand and ninety and four-tenths (1,090.4) miles. Paid for partly by the State and partly by the towns under what is known as "the money system." The amount received from the State varies with the amount of taxes levied per mile of road, as follows: Where the assessed valuation of property, exclusive of cities and villages, is less than \$5,000 per mile of road, the town receives \$1 from the State for every \$1 locally raised. Where the assessment is over \$5,000 and less than \$7,000, the State pays an amount equal to 90 per cent of the taxes so raised; over \$7,000 and less than \$9,000, the State pays 80 per cent; over \$9,000 and less than \$11,000, 70 per cent; over \$11,000 and less than \$13,000, 60 per cent; and when the assessment exceeds \$13,000, the State pays 50 per cent. Town highways are maintained by towns. The cost of maintenance is borne in the same manner as for construction.

HOW THE IMPROVEMENT WAS FINANCED.

The \$500,000 bond issue was authorized by the board of county supervisors in 1910, and the enabling act was passed by the legislature in 1911. The bonds are issued at the discretion of the county highway commission. One hundred thousand dollars of bonds were issued in 1911, and \$300,000 in 1912 in two lots, \$100,000 in the first lot and \$200,000 in the second lot. In August, 1913, the last \$100,000 worth of bonds were issued. All bonds were issued in denominations of \$1,000 each, numbered from 1 to 500, inclusive, and are divided into five series, A, B, C, D, and E, respectively. The bonds are dated on March 1 of the year of issue, and are payable in installments of 10 bonds each, as consecutively numbered. Except for the last issue, 10 bonds become due 10 years after issuance and 10 bonds each year thereafter until the whole issue has been fully paid. The last issue is payable 10 bonds each year from 1915 to 1924. The interest is paid semiannually. The first \$400,000 issue bears interest at the rate of $4\frac{1}{2}$ per cent and the last \$100,000 at the rate of 5 per cent.

The first issue sold for \$104.01, the second for \$105.53, the third for \$105.5187, and the last for \$100.537. No sinking fund is provided,

as the bonds are serial in character. The principal and interest are to be paid out of the tax levied especially for that purpose. This tax is assessed against all of the property in the county, including incorporated villages.

During the year 1911 the county issued \$33,000 of bonds with which to pay the county's share of the cost of county highways, amounting to 20 per cent of the total cost, thus making the total bond issues \$533,000.

In order to meet the interest charges and take up the bonds as they mature, the average annual outlay, covering the 50-year period from 1912 to 1961, inclusive, will be \$21,735. The county will then have paid out a total of \$1,068,500, of which \$500,000 is the original principal and \$568,500 the total interest charges. If the sinking-fund plan had been adopted instead of the deferred serial method, and 3 per cent could have been realized on the sinking fund, the average annual outlay for interest and sinking fund would have been \$27,432.74, or a total for the 50-year period of \$1,371,637, thus showing a total saving by the adopted plan of \$285,137 over the sinking-fund plan. It is probable that the county would have found it more economical, however, to begin payments the fifth year instead of the tenth year, and to distribute the payments over 25 years instead of 50 years, as the life of the bonds would then more nearly approximate the duration of the improvements. Under such plan the average annual outlay would have amounted to \$34,660, or a total for the 25-year period of \$866,500. The average annual payments would have been \$12,936 more than under the plan adopted, but the total amount paid out would have been \$220,000 less than under the plan adopted, and the roads would have been paid for by the generation which receives the greatest benefit from them. To raise the \$21,730, which will be the average amount required for interest and principal under the plan adopted, will require an annual levy of 1.72 mills on each dollar of the 1915 valuation, but if the bonds had been paid for by the 5-25 year serial plan the rate would have been 2.74 mills on the dollar. Furthermore, the 1.72 mills, or its equivalent, must be levied for 50 years, whereas the 2.74 mills would have been levied only 25 years. All highway taxes are levied of town valuations, and the rates vary in each on account of the variation in assessed values. In 1911 the rate varied from 4.95 mills to 19.1 mills, an average for the whole county of 8.37 mills. In 1913 the rates varied from 4.26 mills to 16.49 mills, an average of 9.39 mills.

ASSESSED VALUATION.

The equalized assessed valuation of property subject to taxation for road purposes in 1910, not including bank stocks, was \$12,338,080, and in 1915, \$13,201,055. The assessed value of real estate in 1910

was \$11,741,490 and in 1915, \$12,633,266, an increase of 7.6 per cent from 1910 to 1915, the period covered by the improvement of the roads. All property in the county is assessed at about 90 per cent of its real value. The bond issue represents about 3.8 per cent of the assessed value.

RECEIPTS FROM TAXATION FOR ROADS.

In 1910 the various towns raised \$76,489.98 for roads. In 1915 there was raised by taxation \$181,988.15, of which \$88,934.83 was for town highways, \$25,625 for State and county highways, \$4,178.32 for interest on State and county highway bonds, \$31,000 for maintenance of county roads, \$22,250 for interest on county road bonds, and \$10,000 for retiring county road bonds.

MANAGEMENT, PERSONNEL, AND COMPENSATION.

All State and county highways are built by contract let by the State highway department, which supervises the construction of such highways. County roads are built by day labor under the supervision of the county superintendent and the county highway commission, while the county superintendent and the respective town superintendents supervise the construction of town roads.

The State highways are designated by act of the legislature, but the choice between two or more routes is made by the State highway department. The board of supervisors designates county highways and county roads; and the town superintendents and town boards designate town roads for improvement.

The method of construction to be followed on State and county highways is determined by the State highway department, with the approval of the county superintendent. The improvements on town highways are designated by the county superintendent of highways.

The body in charge of the bond-built county roads is designated as the Franklin County Road Commission and consists of a president, secretary, and county superintendent of town roads, and two other members. Three members of this commission are appointed by the board of supervisors and are members of that board. The county superintendent occupies a position on the commission by virtue of his office. The fifth member of the commission is appointed by the other four. This commission acts for the county board of supervisors. The compensation of members of the commission is \$4 per day for time actually employed, and expenses. The total salary and expenses of the commission for 1911 to 1913, inclusive, amounted to \$5,596, exclusive of the salary of the county superintendent, which amounts to \$2,000 per annum. An auditor is employed at \$4 per day, a bookkeeper at \$4 per day, and a stenographer

at \$12 per week. These report to the county superintendent, who is supplied with an automobile furnished by the county board of supervisors, and directly supervises all engineering, construction, and maintenance work on county roads.

CONSTRUCTION COSTS.

Previous to 1910, all State and county highways in Franklin County were constructed of plain water-bound macadam. In 1910-11 the bituminous-macadam penetration method was used on State and county highways. The width between ditch lines on State highways is 32 feet, the road surface is 16 feet, and the depth of material is 6 inches. County highways are 26 to 28 feet between ditches, with the macadam 14 feet wide and 6 inches thick.

The stone-surfaced county roads built from bond-issue funds were surfaced to a width of 10 feet and to a depth of 6 inches, and the gravel roads to 12 feet in width and 7 inches in depth. The average width of county roads between ditch lines is 22 feet.

The town highways are usually surfaced with gravel to a width of 9 or 10 feet. The average cost per mile of the various classes of roads is shown in Table 17.

TABLE 17.

State highways (bituminous macadam).....	\$12,000
County highways (bituminous macadam).....	11,000
County roads:	
Macadam.....	3,000 to 4,000
Gravel.....	1,900 to 2,500
Town highways:	
Macadam.....	1,800 to 4,000
Gravel.....	1,500

The above costs include bridges and culverts under 5-foot span. All culverts under 5-foot span are built by the towns, counties, or State, as the case may be, but all bridges over 5-foot span are built by the towns.

An examination of the bridge and culvert situation shows that from 1911 to 1913 the number of wooden bridges decreased from 407 to 355. Stone bridges decreased during that same period from 27 to 6. The number of concrete bridges increased from 62 to 112, and iron bridges from 179 to 192. Concrete culverts increased from 166 in 1911 to 816 in 1913. (See Plate XXI.)

The condition of some of the county roads before and after improvement is shown by Plate XX.

During the construction period common labor cost \$1.75 per day; teams with driver, \$4.25; foremen in charge of sections, \$3.50; subforemen, \$2.50 to \$3; roller operators, \$2.50 to \$3; transit men, \$3 and expenses; chain men and helpers, \$1.50.

During the year 1911 the average cost of engineering on county roads in Franklin County was \$17 per mile of road surveyed. During the year 1912 this had been reduced to \$14.82 per mile for the total of 134.6 miles of road surveyed. As the county does no road work by contract, the quantities are not estimated in advance, and the cross sections are therefore not measured. This fact is largely responsible for the low cost of the surveys.

Most of the stone and gravel was donated. Many of the roads are built of crushed bowlders which have been taken off the fields and piled up at the roadside as fences. In some cases the county has paid for stone, the average being about 5 cents per cubic yard in the field. Where the stone was hauled to the crusher, the farmers were paid about 30 cents per cubic yard for delivering the same.

SURFACE TREATMENT.

Contracts were let during 1914 for the resurfacing of many of the State and county highways. About 45 miles of county gravel and macadam roads were treated with bituminous applications during 1913, at a cost of \$0.011 per square yard. This work was continued during 1914 and a distributor has been purchased for this purpose. The roads are treated to a width of 7 to 10 feet.

EFFECT OF ROAD IMPROVEMENT ON LAND VALUES.

It is estimated that about 75 per cent of the land outside of the State forest reserves is tillable. The other 25 per cent is either covered with stone or so rough that it can not be used except for forest production or grazing.

The average farm contains 116 acres, and the average value of land per acre, including buildings, according to the United States census, was \$32.40 in 1910. The value of good land in the county averages from \$45 to \$50 per acre. A study made in 1912 indicates that farms for sale on macadam roads were more valuable than those located on earth roads. Eleven farms containing 2,046 acres and located on earth roads were offered at an average of \$23.48 per acre, while three farms located on macadam roads were offered at an average of \$106.69 per acre for 239 acres.

Since the improvement of the road between Chateaugay and Chateaugay Lake, about $6\frac{1}{2}$ miles, the value of adjacent land increased from about \$50 to \$60 an acre. The total cost of this road was about \$22,750, while the increased value of three-fourths of the land within a half mile of the road on either side, according to the above figures, amounts to \$31,200. It is estimated that about three-fourths of the land in that part of the county is either under cultivation or is tillable.

A few specific instances showing the increased value of land on roads which have been recently improved are presented in Table 18. The increased value does not include the increases due to the construction of buildings or other improvements. These farms are located in various parts of the county, and were selected at random, though it is believed that they are fairly representative.

TABLE 18.—*Increased values of certain farms located on roads recently improved.*

Type of road before and after improvement.		Size of farm.	Value per acre before improvement and from 2 to 3 years after.		Increase per acre.	Per cent of increase.	Miles to nearest shipping station.
Before.	After.		Before.	After.			
		<i>Acres.</i>					
Earth, sandy.....	Bituminous macadam.....	84	\$95	\$119	\$24.00	25.3	3.0
Part sandy.....	do.....	50	40	60	20.00	50.0	3.5
Fairly good.....	do.....	50	35	50	15.00	42.8	9.0
Loam, steep grade.....	Macadam.....	275	14	30	16.00	114.1	7.0
Earth and sand.....	do.....	120	40	50	10.00	25.0	1.5
Earth, sandy.....	Bituminous macadam.....	77	52	64	12.00	23.1	1.0
Do.....	do.....	53	77	84	7.00	9.1	2.0
Earth, part sandy.....	do.....	125	46	52	6.00	13.0	2.5
Earth, very bad.....	Macadam.....	390	40	50	10.00	25.0	4.0
Weighted average.....		136	40.70	53.20	12.50	30.7	3.7

If it is assumed that farm values have increased at the rate of \$10 per acre on all of the 492 miles of roads improved in the county, and that this increase affects only 40 per cent of the land lying within one-half mile of the roads on both sides, the total increase for the whole county would be \$1,259,520. On the same basis this increase in valuation would amount to \$345,600 for the 135 miles of bond-built county roads.

SOME EXAMPLES SHOWING SAVING IN HAULING COSTS.

Information covering a period of 3 years was obtained from 12 farmers and dairymen, and on this information estimates of hauling costs before and after the roads were improved are based. It was found that the average haul was 5.73 miles, the average cost of man and team \$4 per day, the number of trips per day 1.92 and 2.63, respectively, before and after the roads were improved. The average load on the old roads was 2,392 pounds and on the new roads 5,557 pounds for a two-horse team. Using these figures as a basis a two-horse outfit would haul about 13.2 ton-miles per day on the old roads and about 41.8 on the new roads at an estimated cost of \$0.303 and \$0.096 per ton-mile, respectively, or at an estimated saving by improved roads of \$0.207 per ton-mile.

Hauling costs furnished by a farmer and dairyman who owns a milk condensery at Fort Covington and a creamery at North Bangor deserves special mention. He stated that the cost for hauling

milk from Fort Covington to North Bangor over the old road, a distance of 15 miles, was about 20 cents per can (120 pounds), or about \$0.22 per ton-mile, hauling 25 cans at a load. After the roads were improved he was able to increase the load to 40 cans for a two-horse outfit on the macadam and gravel roads. This is at the rate of \$0.125 per ton-mile for a 15-mile haul, assuming the cost of team and driver to be \$4.50 per day, which is slightly above the average for the county. (See Pl. XXIII, fig. 2.)

In May, 1914, this man purchased an automobile truck with which to do his hauling. The truck cost \$1,750, and it is now doing the work formerly done by three 2-horse outfits. (See Pl. XXIII, fig. 3.) It makes two trips a day from North Bangor to Fort Covington and return, and also one trip a day to Westville, distance $7\frac{1}{2}$ miles; total distance traveled, 75 miles per day; distance loaded, 37.5 miles. The load consists of 50 cans of milk (120 pounds each), a total net load of 3 tons, or 112.5 ton-miles per day. The weight of the truck empty is 4,800 pounds. The estimated cost of operating this truck for 200 working days when roads are not covered with snow is given in Table 19.

TABLE 19.

First cost, 3 ton truck.....	\$1, 750.00	
Fixed charges:		
Interest.....	\$87.50	
Insurance.....	85.00	
Driver.....	500.00	
Garage.....	50.00	
		722.50
Operating charges:		
Depreciation.....	262.50	
Gasoline.....	250.00	
Tires.....	400.00	
Maintenance.....	175.00	
Oil and grease.....	50.00	
		1, 137.50
Total.....		1, 860.00

The present cost per day, then, is \$9.30, which for 112.5 ton-miles per day, or 22,500 ton miles in 200 days, makes the cost per ton-mile \$0.0825. This man's hauling costs would therefore appear to have been reduced by improved roads and the automobile truck as shown in Table 20.

TABLE 20.

Horses and wagon on old roads.....	\$0.22
Horses and wagon on new roads.....	.125
Automobile truck on new roads.....	.0825

APPROXIMATE TONNAGE HAULED TO MARKET OR SHIPPING POINT.

Table 21 gives the approximate tonnage of farm and forest products hauled to market over the county roads. This table is based on the production for 1910, as shown by the United States census upon the record of incoming and outgoing rail shipments, and upon information received from merchants and others in the county.

TABLE 21.

Product.	Annual tons hauled.	Product.	Annual tons hauled.
Hay.....	15,000	Fruits.....	500
Potatoes.....	25,000	Poultry products.....	250
Milk, cream, butter, etc.....	32,000	Animal products.....	1,500
Miscellaneous grains.....	600	Forest products, including cordwood..	15,000
Hops.....	237		
Maple products.....	200	Total.....	90,287

APPROXIMATE TONNAGE HAULED TO FARMS.

The estimated annual tonnage hauled over the roads from railroad stations to farms is shown in Table 22. It will be seen that the estimated total annual traffic hauled over the country roads amounts to 145,287 tons. The traffic area for the county is estimated at 330,400 acres. The total tonnage hauled, therefore, amounts to 0.4 of a ton per acre. The average distance hauled is about 5.5 miles, which makes a total traffic for the county of about 799,078 ton-miles. The average cost of hauling over the old roads, based on the observations previously referred to, amounted to \$0.303 per ton-mile, and on the new roads to \$0.096 per ton-mile, making a saving of about \$0.207 per ton-mile, or a total annual saving for the county of approximately \$150,372. It is estimated that about one-third of this traffic passes over the bond-built roads, and, therefore, only about one-third of this saving, or \$50,124, should be credited to these roads.

TABLE 22.

Material hauled.	Annual tons hauled.	Material hauled.	Annual tons hauled.
Fertilizer.....	5,000	Feed.....	15,000
Manure.....	10,000	Freight direct from railroad.....	5,000
Coal.....	15,000		
Hardware and building supplies.....	5,000	Total.....	55,000

During the spring of 1914, as a direct result of road improvement, two automobile bus lines were established—one between Malone and St. Regis Falls, 26 miles one way, and one between Malone and Fort Covington, 16 miles one way. The St. Regis line makes one trip a day, with rates of \$1 for one way, or \$1.60 for the round trip. The

Fort Covington line makes two trips a day and charges \$1 for the round trip. They have a regular schedule as to time of arrival and departure from terminals and intermediate points, and a schedule of rates for intermediate points.

DALLAS COUNTY, ALA.

An object-lesson road constructed in 1909 under the direction of the Office of Public Roads of the United States Department of Agriculture started the movement for better roads in Dallas County, and in May, 1910, an election was carried for the issuance of \$250,000 in county bonds. This sum was supplemented by an additional bond issue of \$100,000 in July, 1912. The economic studies were made in March, 1911, April, 1912, April, 1913, April, 1914, and a short study in October, 1915.

The county is in the central part of the State and has an area of 940 square miles, or about 612,480 acres, of which about 256,000 acres constitute improved farm land. The principal product of the county is cotton, but about 40,000 acres are in corn, hay, and forage. Most of the county is level or gently rolling, and a small portion is hilly. The soil in the eastern part of the county is a sandy loam, while the western part is in the prairie section or Black Belt, which takes its name from the fact that the soil is very dark. The population of the county in 1910 was 53,401, of which 13,649 were comprised in the population of Selma, the county seat and principal city. There are about 1,000 miles of public road in the county, of which 217.9 miles, or 21.7 per cent, have been improved up to the year 1915. (See Pl. XXVI.)

HOW THE IMPROVEMENT WAS FINANCED.

The first \$250,000 of bonds voted were sold in two lots of \$100,000 and \$150,000, respectively, on November 9, 1910, and July 3, 1911. The first issue brought a premium of \$4,847.20 and the second issue \$7,875. The \$100,000 of bonds voted in 1912 were sold July 8, 1912, for a premium of \$4,255. Thus the county had a total to apply to its road system of \$366,977.20. The bonds all carry 5 per cent interest and run for a term of 30 years under the sinking-fund method. As no provision had been made to the close of 1915 for a sinking fund it is difficult to forecast just what the tax burdens will be to meet the indebtedness. It is understood that the county commissioners plan to buy up the bonds as fast as a surplus accumulates in the county treasury rather than maintain a sinking fund. This method would be far preferable to the maintenance of a sinking fund, provided the holders of the bonds are willing to surrender them at the amount of the original purchasing price, but this is an uncertainty, since it does not appear that the bonds have been issued subject to

call. If the bonds are retired on a straight sinking-fund basis and it is assumed that 3 per cent is realized from the sinking fund, the annual amount necessary to be raised would be \$7,356 for sinking fund and \$17,500 for interest, or a total average annual outlay of \$24,856, and the total cost to the county for principal and interest would be \$745,700. If 4 per cent is realized on the sinking fund the annual amount necessary to be raised would be \$6,240 for sinking fund and \$17,500 for interest, a total average annual cost for principal and interest of \$23,740, or a grand total for the 30-year period of \$712,200. Contrasted with this method, it may be pointed out that if the bonds were issued on a 5-30 year deferred serial method the annual cost would be \$22,166 and the total cost \$665,000, or a saving as compared with the sinking-fund method of \$80,702 where only 3 per cent is realized on the sinking fund, or \$47,216 if 4 per cent is realized. It therefore follows that if the commissioners take up the bonds only as they find it practicable, the relative economy as compared with the other two methods can not be determined until it is known what success they meet with in redeeming the bonds. The deferred serial method would have been free from this element of uncertainty, and the necessary tax rate could have been ascertained definitely.

There is no special tax levy to provide funds for the road bonds, as all the payments for interest and sinking fund are taken from the general county levy. In 1910 the general levy for county purposes was 5 mills on the dollar, in addition to which there was a levy of 2 mills for bridges and 6.5 mills for State purposes, or a total of 13.5 mills. In 1915 the tax rate had increased to 7 mills for county purposes, the bridge tax had decreased to 0.5 mill, and the State tax remained at 6.5 mills, making a total of 14 mills, or an increase over the 1910 rate of only 0.5 mill. There is also a statute labor or head tax of 10 days, which may be paid in cash at the rate of 50 cents per day. The poll tax, from which \$1,519 was derived in 1915, is applied to schools. Just what the tax burden for the road bonds should be under the various possible plans may be indicated as follows: The assessed valuation for 1915 was \$14,068,610. It would therefore be necessary to levy on such a valuation a rate of 1.76 mills on the dollar to produce the \$24,856 annually to retire the bonds on the 3 per cent sinking-fund plan, or 1.68 mills to provide the \$23,740 annually necessary if 4 per cent is obtained on the sinking fund. If the 5-30 year serial method had been adopted, the \$22,166 annually required would be obtained by a levy of 1.56 mills on the dollar on the basis of the 1915 valuation. Therefore the construction of the improved roads under the bond issue represents an annual outlay constituting about 12.6 per cent of the total tax burden of the county. This should not prove oppressive, as it is probable that property values will increase and that the rate will correspondingly decrease. Even

on the present basis, however, a \$5,000 farm, assessed at \$3,000, which is about the average, would pay for the improved roads from \$4 to \$5 annually, according to the method which is adopted for payment of the indebtedness.

No aid was granted by the State toward the roads built under the bond issue, but an apportionment of \$2,000 for each of the years 1911, 1912, and 1913 and \$3,271.13 for 1914, or a total of \$9,271.13, was granted by the State toward the cost of other roads whose construction was directed by the State highway department under a plan whereby the State and county paid, respectively, 50 per cent of the cost. Beginning with 1916, State aid must be applied to a trunk-line system designated by the State legislature. The average cost of the 9 miles of gravel road built with the aid of the State was \$1,997.85.

HOW THE ROAD WORK WAS MANAGED.

The roads to be improved were selected by the county board of commissioners, which consists of the judge of probate, who is ex-officio president, and four members. The four commissioners are elected from the four districts of the county for a term of four years and receive \$4 per day for time actually employed, or an average of from \$600 to \$800 per annum each. The commissioners have charge of the roads in their respective districts and employ overseers at \$2 per day for time actually employed. These overseers have charge of the statute labor. The probate judge is elected for a 6-year term from the county at large and his compensation is based on the fee system. There are no other administrative road officials. An engineer was employed by the county board in 1911 at a salary of \$3,000 per annum. His successor received \$2,500 per annum, and the present engineer in charge of road work receives \$150 per month and necessary expenses.

A superintendent of convict forces is employed at \$95 per month, a bridge superintendent at \$100 per month, and a superintendent of maintenance at \$75 per month. These three officials report to the respective commissioners according to the district in which the work is conducted. Most of the construction under the bond issue was by contract either on the basis of a fixed charge per hour for labor and teams or on the unit-cost basis.

Gravel roads aggregating 78.45 miles and sand-clay roads 23.30 miles, or a total of 101.75 miles, were constructed with the bond-issue funds. The county is well supplied with clay gravel and with natural sand-clay. Where the wagon haul was excessive the materials were shipped by rail from the county gravel pit to the siding nearest the proposed improvement. This pit is located on a railroad siding and the material is excavated by steam shovel. The pit has a 28-foot

face, an area of 6 acres, and cost the county \$100 per acre. The maximum output is 30 cars per day and the cost of operation about \$300 per month. The plant handled enough material in a day to supply the railroad with sufficient ballast at 10 cents per cubic yard in addition to the gravel needed for the roads, to pay for the transportation of the road material.

The roads were graded 24 feet wide on embankments and 30 feet wide in cuts. The subgrade was prepared with road machines to an average width of 16 feet. The material, which was hauled in flat-bottom wagons and dumped three loads abreast (for a width of 16 feet), was spread and shaped with a road machine. No roller was used, and the material was consolidated by hauling over each previous day's work. The surface was shaped with a grader to a crown of about three-fourths inch to the foot. The depth of consolidated surface averaged from 7 to 9 inches. Private or farm roads entering on improved roads were surfaced for a distance of about 100 feet, in order to prevent tracking mud upon the gravel surface. Striking contrasts between the old and the new roads are shown in Plates XXV and XXVII.

Owing to the numerous small streams and creeks with large drainage areas emptying into the Alabama River, the cost of the highway system was exceptionally heavy. It has been the policy of the commissioners to bridge these streams with permanent structures of steel and concrete, and, while the bridges and culverts have been economically designed and erected, the number which had to be constructed caused the total cost to form a rather large percentage of the total expenditure for the road system. From the report of the county engineer on March 1, 1912, it is found that out of a total of \$345,293.19 the expenditure for bridges was \$83,192. Out of \$252,924 expended from bond funds in 1912, a total of \$32,570 was expended for 46 steel and concrete bridges, 11 concrete culverts, and 19 steel bridges paid for but not erected. The average cost of the roads constructed with bond-issue funds, including the outlay for bridges, was \$3,606.66 per mile.

Aside from the bond-built roads and the State-aid road, the county had improved, up to the year 1915, 69.65 miles of gravel and 37.5 miles of sand-clay road. These were built by contract and by the convict forces. On April 1, 1912, the county owned 93 mules and considerable equipment, the whole valued at \$27,922.

An average of from 20 to 60 convicts are regularly employed on road work, and these are worked in one gang. In 1913 the cost of operating the camp, including feed for four mules, was estimated at 50 cents per day per convict. Information furnished by the county officials in 1913 indicates that the average cost of building gravel

roads with this gang was \$3,000 per mile, and of sand-clay roads from \$1,500 to \$1,800 per mile. • The gravel roads were surfaced 16 feet wide and 9 inches deep on road beds varying in width from 24 to 30 feet.

HOW THE ROADS ARE MAINTAINED.

The improved roads in the outlying districts are in excellent condition, but for a mile or two out of Selma some of the roads built in 1911 are rough and need to be resurfaced. The heavy repair and maintenance work is done by a gang employed continuously throughout the year, and composed of a foreman, 8 or 10 men, 10 mules, 2 road machines, 5 wagons, 2 drag scrapers, and some drags. The foreman is paid \$75 per month, labor \$1 per day. No information was obtainable as to mileage maintained and cost per mile. Some small repairs are looked after by the man-and-cart patrol system. Each outfit costs about \$32 per month—\$20 for the man and \$12 for the mule. There are no toll roads in the county.

EFFECT OF ROAD IMPROVEMENT ON LAND VALUES.

As the road improvement was begun in 1910 the taxable valuations for that year and for 1915 have been compared to ascertain whether there has been an appreciable increase since the roads were improved. The total valuation in 1910 was \$12,692,800, and in 1915 it was \$14,068,610. As the effect of the road improvement would only be reflected in the real estate values, it was ascertained that real estate in 1910 was assessed at \$7,604,440 and in 1915 at \$8,534,445, an increase of 12.2 per cent in 5 years. This is not a radical increase, but is sufficient to indicate a normal, healthy development.

Personal investigation of sale values along the improved roads brought out the fact that the road improvement had added at least \$5 to the value of each acre of land within one-half mile of the roads. On this basis the aggregate increases due to the road improvement would be \$325,600. Of many specific cases recorded, it might be mentioned that one farm of 100 acres, assessed before the road improvement at \$6 per acre, sold in 1914 at \$48 per acre. The increase was entirely attributed to the road improvement. Another farm which was on the market at \$10 per acre before the roads were improved was recently sold at \$50 per acre. Tracts of land on another improved road which sold for \$8 to \$10 per acre before the road was improved, were recently sold again at from \$20 to \$25 per acre. Quite a number of instances were recorded of increases of from 50 to 150 per cent in value.

EFFECT OF ROAD IMPROVEMENT ON TRAFFIC.

The county is self-supporting from an agricultural point of view, and its outgoing shipments of general farm crops far exceed its incoming shipments, as indicated by the fact that in 1912 the outgoing

shipments of farm products at Selma alone amounted to 9,452.8 tons, as compared with only 569.9 tons incoming shipments of farm products, both exclusive of cotton. The farmers in this section are no longer relying solely upon cotton, but are devoting themselves more and more to general farm crops and to the raising of live stock and poultry. (See Pl. XXVIII.)

An indication of this change in agricultural methods is shown by the facts that there were 12 silos built in the county in 1914 and 42 in 1915, and that a creamery was built in Selma in 1915. This creamery now produces 1 ton of butter each week, requiring about 3 tons of cream, which is hauled in over country roads an average distance of about $4\frac{1}{2}$ miles.

Nearly all products, except such as are consumed on the plantations, are hauled over the public roads to Selma. Comparatively little shipping is done from local stations. There is some shipping from Marion Junction, the radius for which is about 5 miles. The total rail shipments from Marion Junction in 1913 included 5,100 tons of hay, 2,500 bales of cotton, and 26 carloads of live stock.

The average load on the old roads was about 1,500 pounds, and on the new roads is at least 2,500 pounds, although much larger loads are frequent. On one of the improved roads about 10,000 pounds of bridge steel were hauled with 4 mules. From 8 to 10 bales of cotton or from 2 to $2\frac{1}{2}$ tons are frequently hauled over the improved roads with 2 mules.

In 1915 there were 305 automobiles registered in the county, and it is estimated that at least one-half of the traveling salesmen who operate out of Selma use motor vehicles. One refining concern sends its motor truck all over the county. Three bottling works operate 5 motor trucks on country roads. Motor trucks also operate between Selma and Marion Junction, 14 miles, and Selma and Orrville, 16 miles, carrying supplies for merchants. The cost of operating these trucks per month is about as shown in Table 23.

TABLE 23.—*Cost of motor truck operation.*

Item.	Selma to Orrville, 25 trips, average load, 2 tons.	Selma to Marion Junction, 42 trips, average load, $1\frac{1}{2}$ tons.	Item.	Selma to Orrville (16 miles).	Selma to Marion Junction (14 miles).
Insurance.....	\$14. 17	\$14. 17	Depreciation.....	² \$30. 00	² \$42. 00
Privilege.....	¹ 12. 50	12. 50	Repairs.....	18. 00	1 10. 00
Driver.....	30. 00	30. 00	Interest.....	12. 00	18. 50
Helper.....	15. 00	15. 00	Total.....	159. 17	210. 28
Gasoline.....	25. 00	58. 64			
Tires.....	¹ 12. 50	1 10. 00			

¹ Estimated.

² Equivalent to 20 per cent.

The Orrville truck cost \$1,800 and the Marion Junction truck \$2,500. Assuming that they are loaded each way, the former will haul 1,600 ton-miles per month, at a cost of 9.9 cents per ton-mile, and the latter 1,764 ton-miles a month, at a cost of 11.9 cents per ton-mile.

The cotton crop which is produced on 160,000 acres constitutes the bulk of hauling. Each bale represents 500 pounds of lint and 1,000 pounds of seed. The average annual crop for the county does not amount to more than 37,500 tons, including seed. Practically all of this is hauled for some distance over the improved roads. General farm crops produced on about 40,000 acres amounted to about 30,000 tons in 1910, and this has materially increased since that time. Approximately 18,000 tons (or 900 pounds to the acre) are hauled over the roads. It is estimated that about 20,000 tons of fertilizer and about 10,000 tons of miscellaneous products and supplies are hauled over country roads from Selma and other distributing points to plantations in Dallas and adjacent counties. This makes a grand total tonnage hauled over country roads, as shown in Table 24:

TABLE 24.

	Tons.
Cotton and cotton seed.....	37, 500
General farm products.....	18, 000
Fertilizer.....	20, 000
Miscellaneous.....	10, 000
Total.....	85, 500

The whole county constitutes the traffic area for the improved roads, but there are only 200,000 acres in crops. The total tonnage therefore represents about 0.11 ton per traffic acre or 0.43 ton for each acre in crops. The maximum haul for the county is about 28 miles, and the average haul from 8 to 10 miles. The average haul on the bond-built roads is about 8.4 miles. The total hauling over the bond-built roads is probably about 610,000 ton-miles, or about 84 per cent of the total. On the old roads the cost of hauling averaged about 30 cents per ton-mile, and on the new roads about 15 cents. The total annual saving, therefore, might be estimated at about \$90,000.

LAUDERDALE COUNTY, MISS.

Road improvement was agitated in Lauderdale County in 1910, and after a brief educational campaign, bonds were issued by the county board of supervisors upon petitions submitted by taxpayers. The first bonds were issued September 1, 1910, and at various times thereafter to March 1, 1915, until they aggregated \$500,000. They were not issued as county liabilities, but were chargeable to the respective beats, which correspond to townships in other States. The work of construction was begun during the spring of 1911 and the

last of the improvements contemplated in the first \$450,000 of bonds issued were completed in the spring of 1915.

The county is somewhat larger than the average and has an area of 770 square miles or 448,000 acres. Less than one-fourth of the land is actually under cultivation. The population of the county in 1910 was 46,919, of which Meridian, the county seat and principal city, comprised 23,285. The products of the county are quite varied, as indicated by the fact that in 1910, 19,257 bales of cotton, 265,291 bushels of corn, 44,372 bushels of oats, 18,000 bushels of dry peas, and 121,000 bushels of potatoes were produced, and there were from 30,000,000 to 40,000,000 feet of yellow-pine lumber cut for shipment. Stock raising is also becoming an important industry.

The topography of the county is for the most part hilly, with small areas of rolling land and level creek bottoms. The soil varies from sandy loam to bright-red clay. During certain seasons the natural-soil roads are impassable for loaded vehicles, and therefore improved roads mean a great deal to the rural population.

The economic studies were made in March, 1911, and in April of 1912, 1913, 1914, with a short study in November, 1915.

HOW THE IMPROVEMENT WAS FINANCED.

Between September 1, 1910, and March 1, 1915, Beat 1, which includes the city of Meridian, issued \$450,000 and Beat 5 issued \$50,000 of road-improvement bonds. The total of all outstanding bonds must not, by the State law, exceed 10 per cent of the assessed valuation of all the taxable property in the county.

The bonds were issued by the county board of supervisors in accordance with the general law of the State. This law, adopted in 1910, provides that any county or district thereof may issue bonds on petition of 20 per cent of the qualified electors, provided the issuance of such bonds is not petitioned against by an equal number of qualified electors. If 20 per cent of the qualified electors petition against the issue of the bonds, then an election must be held, at which a majority vote decides the question for or against the issue. The bonds were issued without resorting to an election, except the last issue of \$50,000. Table 25 shows the amount of bonds issued, dates of issuance, selling price, and interest.

TABLE 25.—Road-improvement bonds issued by *Lauderdale County*.

Date sold.	Amount.	Price obtained.	Interest.	Beat No.
Sept. 1, 1910.....	\$50,000	\$50,050	<i>Per cent.</i> 5½	1
Do.....	150,000	150,275	5	1
Mar. 1, 1913.....	100,000	100,110	5	1
Mar. 1, 1914.....	100,000	100,000	5½	1
Mar. 1, 1915.....	50,000	51,041	5½	1
Apr. 5, 1912.....	50,000	51,050	5½	5
Total.....	500,000	502,526	-----	-----

The issues of 1910 to 1914, inclusive, have been spent in building roads in Beats 1 and 5, but no roads were improved with this money inside the city of Meridian. About one-half of the \$50,000 issue of March 1, 1915, will be spent inside the city limits in connecting up the streets with the county roads.

The general law of Mississippi requires that all road-improvement bonds must be paid off within 25 years, and in annual installments after 10 years from the date of issue, and that they shall bear not to exceed 6 per cent interest, payable annually or semiannually. The bonds were issued in blocks of \$500 each.

The first issue for Beat 1 of \$50,000, bearing $5\frac{1}{2}$ per cent interest and dated September 1, 1910, is payable as follows: 28 bonds of \$500 each, payable each year on September 1, 1922 to 1924, inclusive, and 16 bonds on September 1, 1926.

The second issue for Beat 1 of \$150,000, bearing 5 per cent interest and dated September 1, 1910, is payable as follows: 28 bonds of \$500 each, due September 1 each year from 1925 to 1934, inclusive, except in 1926, when 12 bonds become due; in 1935, 36 bonds become due.

The third issue for Beat 1 of \$100,000, bearing 5 per cent interest, and dated March 1, 1913, is payable as follows: 13 bonds of \$500 each, due each year on September 1, 1923 to 1937, inclusive, and 5 bonds on September 1, 1938.

The fourth issue for Beat 1 of \$100,000, bearing $5\frac{1}{2}$ per cent interest and dated March 1, 1914, is payable as follows: 13 bonds of \$500 each, due each year on September 1, 1924 to 1938, inclusive, and 5 bonds on September 1, 1939.

The fifth issue for Beat 1 of \$50,000, bearing interest at the rate of $5\frac{1}{2}$ per cent and dated March 1, 1915, is payable as follows: 6 bonds of \$500 each, due each year on March 1, 1926 to 1935, inclusive, and 8 bonds of \$500 each, due each year on March 1, 1936 to 1940, inclusive.

The issue for Beat 5 of \$50,000, bearing $5\frac{1}{2}$ per cent interest, and dated April 5, 1912, is payable as follows: 6 bonds of \$500 each, due each year on September 1, 1923 to 1927, inclusive, and 7 bonds of \$500 each, due each year on September 1, 1928 to 1937, inclusive.

The amount of interest which must be paid before the \$500,000 of bonds are retired according to the plan above outlined will amount to about \$472,232.

While the deferred serial method adopted by Lauderdale County is recognized generally as providing greater security and economy than the sinking-fund method, it would not seem wise to defer the beginning of the bond retirement to the tenth year. If a portion of the principal is paid between the fifth and tenth years, the burden of taxation is lightened by reason of being spread out over a longer period of time. If this is not done, the taxpayers will have expe-

rienced the benefit of the roads for 10 years at a low financial outlay, represented by payments of interest, and then when the great contrast between the old conditions and the new will have passed out of their minds they will suddenly be called upon to assume an increased financial burden in order to provide funds for the retirement of the principal.

The actual tax rate levied for interest on bonds in 1914 in Beat 1, which includes Meridian, was 1.5 mills and in Beat 5, 2.9 mills. In 1915 these rates had increased to 1.8 mills for Beat 1 and 3.4 mills for Beat 5, based upon the 1915 valuation of \$12,874,856 in Beat 1 and \$864,010 in Beat 5. If the bonds had been issued so as to have the payments begin the sixth year and continue to the twenty-fifth year, inclusive, the rate necessary to meet both interest and principal of \$450,000 in Beat 1 would have been 2.53 mills, based on the 1915 valuation, or 0.88 mill more than the average of the rates actually levied for those two years. In Beat 5 the rate necessary to retire the bond issue on the same terms would average 4.28 mills, or 1.18 mills higher than the rate actually levied in 1915. Thus it appears that with tax rates almost as great as would be necessary under the 5-25 year plan the county is only succeeding in meeting interest charges.

It would be well if counties could so arrange their financial measures and so time the meeting of their obligations as to make the burden comparatively light at the very outset, thus giving the people a chance to develop their resources through the improvement of the roads. To do this the cost burden should be distributed so equitably over a period of years that it will avoid the two extremes of excessive tax levies on the one hand to pay off the debt too quickly, and the extension on the other hand of the debt beyond the life of the utility in order to obtain a low tax rate. An examination of the bond issue indicates that if the county had adopted the 5-25 year deferred serial method the total payments would be \$65,357 less than they will be under the method actually adopted, if no sinking fund is established. As against this large difference it should be stated that the taxpayers are having the use of the money which they would have paid out if they had elected to retire the bonds more expeditiously. It is therefore a question as to whether this convenience is worth the price.

Taxation in the county does not differ materially from the rates in other localities, as in 1911 the total for all purposes, including the State tax, was 15.4 mills on the dollar. In addition to this property tax there is a commutation tax of \$2 for road purposes and a poll tax of \$2 for schools. In 1915 the average levy was 16.6 mills, of which the road-bonds tax comprised an average of about 1.6 mills and produced about 9.4 per cent of the revenue; the tax for maintenance

of the bond-built roads comprised 1 mill and produced about 4.9 per cent of the revenue; and the general road tax was 1 mill and produced about 6 per cent of the revenue, thus showing that the public-road revenue of the county comprised about 20 per cent of the total revenue of approximately \$269,500.

The county road tax is levied against all taxable property in Meridian, but about one-half of the proceeds is used for streets inside the corporate limits. Since 1911 the tax rate for the city of Meridian has increased only 0.4 mill, in spite of the fact that it is paying 2.8 mills for interest and maintenance of bond-built roads. The rate for Beat 1, outside of the city, increased 3.4 mills during the same period, and the rate for Beat 5 increased 7.5 mills. The rate in Beats 2, 3, and 4 increased 0.6 mill, but none of the bond-built roads are located in those beats.

The general bonding law of the State requires that the tax for payment of interest and principal on the bonds be a special tax instead of having any of the expenditure paid out of other funds.

HOW THE WORK WAS MANAGED.

The roads constructed from the proceeds of bond issues were built by contract under the general direction of a county highway commission, consisting of three members appointed by the county board of supervisors for a term of 4 years. All important actions of the commission, such as letting contracts and paying out money, are approved by the county board of supervisors. The commission employed an engineer, and all work was done under his immediate direction. He made the surveys and prepared the plans, specifications, and estimates, which were approved by the commission and the board of supervisors before the contracts were let. All bills were checked by the engineer, approved by the commission, and paid on the order of the board of supervisors.

Positions on the road commission were honorary, and the commissioners acted without salary, but received \$50 per annum for expenses. The commission went into office when the first bonds were issued, and has continued in office up to the present time with some changes in personnel. The engineer to the commission received a salary of \$250 per month and the use of an automobile. He continued in office from the time the work started until the work was finished, about April 30, 1915. During the construction period an assistant engineer was employed by the commission at a salary of \$90 per month. A new engineer was employed on May 1, 1915, to complete the work under the \$50,000 bond issue of March 1, 1915. His salary is \$135 per month, but is partly paid by the county board of supervisors for services rendered in connection with laying out roads for the county convict road forces. Before the bonds were issued

the county convict forces built roads without engineering advice or assistance, but the benefits resulting from the employment of a competent engineer have become so apparent in the county that no work is now done by the convict forces without first calling upon the engineer to survey and lay out the work to be done.

Ten main market roads radiating from Meridian like the spokes from the hub of a wheel (see Pl. XXXI) and one branch to a main road, aggregating $51\frac{3}{4}$ miles, were macadamized, and in Beat 1 the distances from the ends of the macadam portions to the beat line were surfaced with sand-clay, the total of this latter type in Beats 1 and 5 aggregating 45 miles. The improved roads, therefore, comprise a total of 96.75 miles, or about 12 per cent of the total of 800 miles in the county. The roads were graded 22 to 24 feet wide in fills and 28 to 30 feet wide in cuts, with 4-foot shoulders and 3-foot ditches. The macadam surfaces were from 14 to 16 feet wide and 6 inches thick consolidated. The sand-clay treatment usually extended from ditch to ditch. Natural sand-clay mixtures were principally used for this construction. The material for the macadam construction consisted of novaculite imported by rail from Tamms, Ill., a distance of 300 miles. The stone cost \$1.10 per ton of 2,160 pounds, f. o. b. Meridian. The gravel used was shipped in by rail from Iuka, Miss., and cost \$1 per ton f. o. b. Meridian, of which 30 cents was for material and 70 cents for freight. The weight was from 2,700 to 3,000 pounds per cubic yard. The average cost of constructing the roads, exclusive of bridges, was about \$6,500 per mile for macadam and \$2,000 per mile for sand-clay. The general average for the entire mileage was about \$4,666 per mile. Most of the bridges were built of wood at a cost of about \$3 per running foot.

For the ordinary road work of the county the convicts, averaging from 65 to 70, are regularly employed. These are divided into three camps and are used for grading and the building of sand-clay roads in the outlying districts, and for general maintenance work on all county roads. The cost of feeding, clothing, guarding, and medical attention, and the cost of teams and equipment, are paid out of the general funds of the county. The total cost of maintaining the three camps is about \$38,600 per annum, and during the past 5 years they have constructed about 50 miles of sand-clay roads. This work was principally that of extension from bond-built roads to the county line. All road and bridge work in this county, amounting to more than \$50, except that which is done by the convicts, must be done by contract. Very little work has been done, however, except by convicts and under the bond issues. The remarkable difference between a good and bad road is shown in Plate XXXII.

HOW THE ROADS ARE MAINTAINED.

An excellent provision in the general law of the State requires that a special tax of not less than 1 mill shall be levied for the maintenance of all roads constructed by means of bond issues. This fund is kept separate from all other funds and can be used only for maintenance. The result of this provision is that instead of deteriorating the roads have actually improved from year to year, and were in excellent condition at the time of our inspection in November, 1915. About a year after the gravel-macadam roads had been built, they were surface-treated with bituminous material, one-half to three-fourths gallon per square yard, and sand or slag screenings, at a total cost of about 7.3 cents per square yard. The roads are not considered finished until they have received this surface treatment. The width treated varies from 12 to 14 feet. All macadam roads in the county are now surface-treated, except 7 miles on the Russell Road and 2 or 3 miles on the Marion and Eighth Street Roads, which will be treated in the spring of 1916. The machinery, which was furnished by the contractor, consisted of rotary sweepers, compressed-air machine and tank, pressure distributors, and tank wagons for hauling heated material. Taking two of the principal roads, the following data show the cost of this work and afford a basis for estimating the cost for the whole county:

ASYLUM ROAD.

40,815 square yards; for purchase of material and its application at 5½ cents per square yard.....	\$2, 244. 83
Additional expenses:	
Hauling hot asphalt.....	\$103. 60
Hauling sand.....	251. 50
Traction-engine engineer, fireman, coal, etc.....	125. 77
Spreading sand.....	179. 80
Heating asphalt.....	80. 00
Incidentals (shovels, repairs, etc.).....	10. 94
Patching.....	106. 30
Hauling water for traction engine.....	25. 00
Total.....	882. 91
Grand total.....	3, 127. 74
Average cost per mile (for the 5 miles).....	\$625. 54
Average cost per square yard.....	. 0766

POPLAR SPRINGS AND MARION ROADS.

84,257 square yards; for purchase of material and its application at 5 cents per square yard.....	\$4, 212. 85
Additional expenses:	
Hauling hot asphalt.....	\$252. 40
Hauling sand.....	791. 62
Traction-engine engineer, fireman, coal, etc.....	284. 45

Additional expenses—Continued.

Spreading sand.....	\$285.85
Heating asphalt.....	130.00
Incidentals (shovels, repairs, etc.).....	21.87
Patching.....	64.35
Hauling water for traction engine.....	11.25
Total.....	\$1,841.79
Grand total.....	6,054.64
Average cost per mile (for the 10 miles).....	\$605.46
Average cost per square yard.....	\$0.072
Total number of square yards treated up to April, 1914.....	125,072
Total cost.....	\$9,182.38
Average cost per mile over entire 15 miles.....	\$612.16
Average cost per square yard.....	\$0.073

The material was purchased and applied by contract at a fixed charge per square yard. The cost of this treatment and all additional expenses shown above were paid by the county from the bond-issue funds.

When roads begin to show signs of wear they are patched and re-treated. About one-fourth gallon of the material per square yard is used in the second treatment and the cost averages about \$400 per mile, which includes \$20 to \$25 per mile for patching. The second treatment and all subsequent repairs are paid for out of the maintenance funds.

For keeping ditches open and for taking care of other small repairs, one man is constantly employed in Beat 1. He furnishes a horse, wagon, and small tools and is paid \$80 per month. Extra labor is employed to assist him when necessary.

The sand-clay roads are worked over with road machines and dragged with split-log drags as often as necessary. The bond-built roads are maintained under the direction of the county highway commission, with the approval of the county board of supervisors.

There are no toll roads in the county.

EFFECT OF ROAD IMPROVEMENT ON LAND VALUES.

The taxable valuation in Lauderdale County in 1911 was \$15,839,185, including the city of Meridian and the railroad property, and had increased in 1914 to \$20,095,110.50. As the road improvement would have no direct bearing upon the assessed valuations of city and railroad property, a comparison of real-estate values outside the city of Meridian would afford more illuminating information in this connection. Such comparison shows that in 1911 the total assessed valuation of real property outside of the city was \$2,757,546 and that it had increased in 1914 to \$3,183,809, an increase during this period of road improvement of 15.4 per cent. A rather striking

fact in connection with the road improvement was that about 83 per cent of the tax for the payment of interest on bonds in Beat No. 1 is paid by the city of Meridian, although none of the roads are located within the corporate limits.

Personal investigation as to the effect of the road improvement on land values brought out many specific incidents of increases in values from 50 to 500 per cent coincident with the improvement of the roads. Lands 5 miles out from Meridian that were held at from \$15 to \$20 per acre before the roads were improved sold after the roads were improved for \$50 per acre. For the purpose of illustrating more specifically the remarkable effect of the road improvement on property values, the following examples were selected on a single road leading out from Meridian:

A tract $4\frac{1}{2}$ miles from Meridian, containing 40 acres, cost \$1,000 in 1911, and in March, 1912, was sold for \$1,900.

A tract containing 13 acres cost \$1,000 in February, 1911, and was sold in the same year, after the road work had begun, for \$2,000.

A tract containing 20 acres, 4 miles from Meridian, cost \$500 in 1907; 13 acres sold in 1912 for \$1,500.

An estate 4 miles from Meridian, containing 40 acres, was purchased in 1908 for \$400. It was sold in 1911 for \$1,700 after construction started, and was estimated to have been worth \$2,500 in 1912.

A farm 5 miles from Meridian, containing 120 acres, was bought in 1907 for \$900, and was sold in 1912 for \$4,200.

A farm $4\frac{1}{2}$ miles from Meridian, containing 200 acres, was estimated to have been worth \$5,000 in 1911, but after the road was completed the owner refused an offer of \$9,500.

A farm 4 miles from Meridian, containing 40 acres, was sold in 1910 for \$2,500; in 1912 the owner refused \$4,500.

The total of 473 acres in these tracts before the roads were improved was \$11,300, or an average of \$23.89 per acre, while after the roads were improved the total value was \$26,100, or \$55.18 per acre, an average increase of \$31.29 per acre, or 131 per cent. Many small tracts of land, 2 or 3 miles from Meridian on the Poplar Springs Road, have sold, since the road was improved, for from \$100 to \$3,000 per acre. This property was all in farms before the road was improved and could have been bought for from \$20 to \$50 per acre. For 3 miles out this road is now lined with magnificent suburban homes.

Estimates of local men versed in real-estate values give the increase in land value, on account of improved roads, at from 25 to 50 per cent. According to the United States census of 1910, the average value of all farm land in Lauderdale County was about \$10 per acre.

EFFECT OF ROAD IMPROVEMENT ON TRAFFIC.

There are five railroads in the county which converge at Meridian. These have a total of about 92.5 miles of road and 23 railroad stations. At Meridian alone 60,000 cars of freight, including 15,000 cars of lumber, are handled annually.

The traffic over some of the roads averages from 25 to 200 loaded vehicles per day at certain seasons of the year, with some of the wagons carrying from 2 to 3 tons. Practical examples of the small tractive resistance on the improved roads were demonstrated by drivers of freight wagons, who unhitched 2 or 3 yoke of oxen when macadam roads were reached and proceeded the remainder of the distance with a single yoke.

The total production of corn, oats, peanuts, peas, potatoes, hay, and forage in 1910 amounted to 17,212 tons, and of cotton and cotton seed 14,442 tons. The production of cotton has been reduced materially since 1910 on account of the boll weevil, but the production of general farm crops has increased probably in about the same proportion. Of these products it is estimated that 20,627 tons were hauled over the country roads to market or shipping point. There is practically no hay or forage hauled out of the county, but more hay is being grown in the county than ever before. In addition to this it is estimated that 4,500 tons of fertilizer and 60,000 tons of lumber are hauled over country roads, making a total of 85,127 tons. It is estimated that about one-half of this, or 42,563 tons, is hauled over the improved roads an average distance of 6 miles, equivalent to 255,378 ton-miles. This tonnage has not materially increased since the roads were improved. The traffic area for these roads embraces about 192,000 acres. The hauling over the improved roads, therefore, amounts to about 0.22 ton per acre for the traffic area.

The average load on the old roads for a two-horse team was 1,500 to 2,500 pounds, and on the new roads from 2,500 to 3,500 pounds. On the basis of an 8-mile haul as a day's work, with an average load of 1 ton and an average wage of \$3 per day for man and team, the average cost per ton-mile over the old roads was \$0.37. Based on a ten-mile haul, an average load of $1\frac{1}{2}$ tons and an average wage of \$3 for man and team, the hauling costs on the new roads average about 20 cents per ton-mile, a saving of 17 cents, or a total annual saving of about \$43,400. If this saving could be applied to the payment of interest and principal, it would be sufficient to retire the \$450,000 bond issue in about 17 years.

EFFECT OF ROAD IMPROVEMENT ON SCHOOLS.

Outside of Meridian there are 78 white and 53 colored schools. In Beat 1, where most of the road improvement has taken place, the average attendance in 1912 was 72 per cent, and in 1913, 81 per cent.

Two schools in Beat 1 were consolidated by reason of the better roads and one school was discontinued, as the children are now able to attend school in Meridian. These two changes have resulted in a net saving to the county of \$100 per month for teachers' salaries.

VALUE OF THE ROADS TO THE COMMUNITY.

In order to bring out an expression of opinion as to the value of road improvement, an inquiry was addressed by a local paper to prominent citizens living on the improved roads. From the replies received, the following quotations are made:

(1) It is impossible to enumerate the advantages of such a road as this; it is the only time in my life that I have ever realized any direct benefits from taxation, but paying taxes for road improvement with me after seeing and realizing what it means to the whole country is a pleasure; and I don't think you can burden a man with taxation when he gets results like this from it.

(2) I have heard compulsory education agitated, but if I was a member of the legislature I would offer a resolution advocating compulsory road construction, for a man that is opposed to it is either ignorant of what it means to him or is a fool, and I think the State ought to look after such people. I get pay over and over every week of my life for what it costs me by watching the school children pass my house to and from school, perfectly comfortable regardless of weather conditions. I am one of the trustees of our school and just a day or two ago I signed the school report, showing a total enrollment of 130 and an average attendance during the month of December of 109. As you know, December was one of the worst months we ever experienced in this county.

(3) I have never made an investment for which I have gotten as much financial returns and satisfaction as I have out of this road. The advancement in property alone has been sufficient to four or five times pay the whole cost of construction, and I don't think the county could make any investment that would bring in as much returns as to build a network of them all over it. It is such a good thing that I want every man in the county to have one just like it, and I am willing to pay my part of the taxes to help him get it.

(4) I live 4 miles from the city and 2 miles from the school. This has been the worst winter that I have ever seen, but there hasn't been a single day that my children haven't walked to school and not a single day have they come home with wet feet; and to think they walked down the middle of the road. Not one of them has been sick with a cold even, while heretofore my doctor bills have been more than my road tax. Talk to me about paying taxes to build roads! I am willing to pay taxes on my pack of fox hounds, my bird dog, my chickens, my horses, and if necessary my wife and children, if they will use it in extending roads like this all over the county. I would rather have my house and 10 acres of land on this road like it is now than have my whole farm on the old road like it was before improvement.

(5) The good roads have made it possible for me to live at my country home and still attend to my business affairs in Meridian, just as easily as though I lived in town. The benefit that strikes me as being most practical and far-reaching is the tremendous increase in real-estate values of country property located on the good roads. I have been especially interested in this feature and have found that in every instance into which I have inquired farms located on the good road have been enhanced in value from 50 per cent to 100 per cent as a result of the building of the good roads. I am heartily in favor of good roads and firmly believe that everybody would be so if they had the opportunity of using one for a short time.

In contrast to the above, the following is quoted from the reply received from a farmer and merchant living on the Bonita Road, which has since been improved (see Pls. XXIX, XXX, and XXXIII):

(6) There hasn't been a time since the 1st of December that I have been able to get anything hauled to my place from Meridian, just 4 miles, for less than 25 cents per hundred; in the majority of instances it has cost me as high as 50 cents, and a good many times it has been impossible to get it at any price; the people in my community have actually had to go without oil for their lamps for a week at the time because they couldn't get it; if these conditions are not a heavier tax on the people than paying for the construction of roads, then I am a bad judge and a bad mathematician.

MANATEE COUNTY, FLA.

The movement to improve the more important roads of the county was begun in 1909 and was due to the fact that fruits and vegetables, for which the climate and soil were particularly favorable, could not be hauled over the sandy roads except at prohibitive cost. (See Plate XXXIV, fig. 1.) Furthermore, the county could not hope to attract tourist travel unless an adequate system of roads was provided. As a result of the movement, \$250,000 of road bonds were voted on September 1, 1909, but on account of injunction proceedings to prevent the issuance of the bonds, work was not begun until the spring of 1911.

The county is located on the west coast just below the lower end of Tampa Bay and has a land area of 1,337 square miles, or 855,680 acres, of which in 1910 only 14,173 acres, or 1.7 per cent of the total, were in improved farms. It is thus evident that the county had scarcely begun to develop its resources at the time the road building was begun. The population was 9,550 in 1910, and several towns in the county were, at that time, rapidly assuming importance as winter resorts. The surface is practically flat and most of it only a few feet above sea level, and the soil varies from light gray sand to fine sandy loam. The principal products are grapefruit, oranges, and other semitropical products, small fruits, and vegetables, which are mostly shipped to northern markets during the winter months.

The economic studies were made in April, 1911, May, 1912, April, 1913, April, 1914, and February, 1915.

HOW THE IMPROVEMENT WAS FINANCED.

The bonds which were issued February 24, 1911, as of September 1, 1909, are 30-year sinking-fund bonds, bearing interest at 5 per cent. A premium of 1 per cent was obtained, making a total available for road improvement of \$252,500. Owing to the fact that 5 per cent is obtained on the sinking fund, the financial burden upon the county is very little more than it would be if the deferred serial method had been adopted. In explanation of how the county was able to secure 5 per cent on the sinking fund, it may be stated that

this fund is deposited with the bond trustees of the county, consisting of three bankers, and by them invested in securities which must be equally as good as the bonds. The trustees are planning to buy up the road bonds whenever their funds are sufficient to do so and the bonds are available for purchase. It is planned to retire \$3,000 of the bonds during 1916. The weakness of the plan adopted lies in the extreme improbability that 5 per cent will continue to be obtained on the sinking fund. If the county succeeds in obtaining over the entire period an average of more than 4 per cent on its sinking fund, it will have accomplished more than could reasonably be expected.

As an indication of how the sinking-fund method compares with the deferred serial method, it might be pointed out that the annual outlay for interest and retirement of the \$250,000 bond issue under the former, with interest on the sinking fund at 4 per cent, would be \$16,957.53, and under the deferred serial method, with the bonds running 5-30 years, the annual outlay would be \$15,833.33. If the county, however, succeeds in obtaining 5 per cent on the sinking fund throughout the entire period the annual outlay will be \$16,262.85.

It would, therefore, appear that if the deferred serial plan had been adopted instead of the sinking-fund plan, with interest on sinking fund producing 4 per cent, a total saving of \$33,725.75 could be realized, but if the sinking fund produced 5 per cent the saving would be only \$12,855.50. This latter sum is, however, equivalent to about 5 per cent of the total bond issue and would have been sufficient to pay for all engineering expenses.

To provide an annual outlay of \$16,262.85, a levy of about 2 mills on each dollar of assessed valuation will be required on the basis of the present assessment, but naturally this rate will decrease as the assessed values increase.

The tax levy for the road bonds in 1910 amounted to 7 mills and in 1915 to 3 mills. The sinking fund contained \$47,396.98 on December 1, 1915, which indicates that the rate of accumulation is greater than necessary to retire the bonds in 30 years.

A comparison of tax rates for the years 1905, 1910, and 1915 reveals the fact that there has not been a very great increase in the rate on account of the road improvement, as the total rates were 24 mills in 1905, 26½ mills in 1910, and 26 mills in 1915, and that while the 24-mill rate produced only \$49,472.86 in 1905, the 26-mill rate produced \$178,420.89 in 1915. In other words, while the tax rate increased during that period only 10 per cent, the receipts increased 260 per cent, indicating a remarkable increase in taxable wealth. While there was a levy of 3 mills in 1915 for road bonds, as compared with no levy for that purpose in 1905, the levy for general county

purposes decreased $1\frac{1}{2}$ mills; the levy for outstanding road warrants, which was only 1 mill in 1905, had been eliminated in 1915; the levy for school indebtedness, which amounted to 3 mills in 1905, was absent in 1915; and the levy of 1 mill for county clerk's office indebtedness in 1905 had been eliminated in 1915; so that these savings more than compensated for the increase due to the road bonds, and made it possible to increase the general levy for roads and bridges of 3 mills in 1905 to 5 mills in 1915, and to make a $3\frac{1}{2}$ -mill levy in 1915 for county buildings. As compared with 1910, it will be noted that the tax rate for 1915 was one-half mill less and that in spite of this reduction the receipts from taxation increased 140 per cent. A further rather interesting comparison is shown by the fact that while in 1905 the roads required 25 per cent of the taxes, they required, including bond taxes in 1915, 33.2 per cent of the taxes.

The road and bridge taxes and the road-bond taxes are levied on all property in the county, including incorporated cities, but one-half of all road and bridge taxes collected from cities are returned to them for the improvement of streets within corporate limits. In addition to the regular road tax there is a statute labor tax of 3 days or \$3 for all residents of rural districts who are non-freholders. The amount of work accomplished and the receipts from this source, however, are inconsiderable.

On January 18, 1910, Englewood district voted \$75,000 worth of road and bridge bonds, but they have not yet been issued. With this money 26 miles of road are to be graded and a portion of the road surfaced with sand-asphalt.

On January 11, 1916, the Sarasota-Venice district voted \$250,000 worth of road and bridge bonds. Of this amount \$210,000 will be expended for roads and \$40,000 for bridges. With the \$210,000 it is proposed to build 34 miles of sand-asphalt roads and grade 14 additional miles. The deferred serial type of bonds will be issued in both of these special districts. They will bear 6 per cent interest and will be retired in 5, 10, 15, and 20 years.

Manatee district is contemplating the issuance of \$239,000 of road and bridge bonds.

The county has \$97,445 of outstanding warrants which were issued for the purpose of building a court house. These bear 6 per cent interest and are to be paid off in five annual installments, covering the period 1913 to 1917, inclusive. There are also \$285,000 of school warrants outstanding. These bear 6 per cent interest and must be paid in 20 years.

From the above it will be seen that the total debt of the county is \$957,445, which represents 11.8 per cent of the 1915 assessed valuation.

HOW THE WORK WAS MANAGED.

The board of county commissioners has sole jurisdiction over the construction and maintenance of public roads, including those built under the bond issues, and consists of five members, of whom one is elected for each of the five districts. They are elected for 2-year terms and receive \$4 per day for time actually employed, not to exceed \$200 per annum. They are allowed mileage extra.

The clerk of the circuit court acts as clerk and accountant to the board of supervisors. The clerk's compensation is derived from fees and he receives no extra compensation from the board.

An engineer was employed by the county commissioners, under whose immediate supervision all bond-built roads were constructed. The engineer received \$10 per day for time actually employed, and expenses. During the construction period he received approximately \$5,000, not including transportation.

The county engineer now employed by the county commissioners for general road and bridge work receives a salary of \$150 per month and the use of an automobile. For the Venice-Sarasota district an engineering firm has been employed to do all engineering work. Compensation will be 4 per cent of the total expenditure of \$250,000.

The roads to be improved were selected by the board of county commissioners prior to the bond election. The bond issue called for the construction of 64.4 miles of road, which was done under contract let by the board. The total mileage constructed was 63.65 or 11 per cent of the total of 575 miles in the county. The accompanying map (Pl. XXXV) shows the roads constructed under the first bond issue and those proposed for construction with bond funds subsequently provided.

The mileage and character of surface constructed under the original bond issue were as follows: Marl and rock, 15.187; marl rock with bituminous binder, 17.050; marl and shell, 9.850; shell, 14.171; brick, 1.00; graded, 6.40; making a total of 63.658 miles constructed. (See Pl. XXXVI, figs. 2 and 3.)

These roads were completed during 1913. The local materials available for road work are soft limestone and flint rock, marl, and shells. The shells are obtained from mounds in various parts of the county, and the other materials are fairly well distributed. These materials are suitable for roads of light traffic, but considerable expense will be entailed in keeping the roads in good condition because of the automobile traffic and the heavy tonnage of fruits and vegetables which pass over them. The expense of shipping in more durable materials led the county authorities to build the roads of local materials and to depend upon bituminous applications to preserve their surfaces.

The marl-rock and limestone roads were surfaced to a width of 9 to 12 feet and were built in two courses. The first course was 6 inches in depth loose and the second course 3 inches loose. The shell roads were surfaced to a width of 9 feet and to a depth of 12 inches loose. All rights of way were cleared to a width of 30 feet.

The average cost of the 63.658 miles built, including culverts and bridges, was \$3,966.50 per mile. The average cost per mile of the shell road was \$2,400; marl-rock macadam, \$3,800; and flint-rock macadam, \$4,700 per mile. A contract let on April 21, 1911, contains the following unit prices: Clearing and grubbing, \$40 per acre; grading, \$0.10 per square yard; filling, \$0.20 per cubic yard; marl in place, \$0.75 per cubic yard; stone in place, \$3.25 per cubic yard; screenings, \$2.75 per cubic yard; sewer pipe in place, \$0.70 per linear foot; and concrete in place, \$6 per cubic yard.

HOW THE ROADS ARE MAINTAINED.

The improved roads have not been systematically maintained. The shells and marl rock of which most of the roads were built are soft, and these materials have not stood up well. The finer materials have worn and blown away and many of the roads are full of ruts and depressions. Some of the worst places have been patched. About 17 miles of rock roads were surface treated with bituminous material when they were constructed, but this treatment has not been renewed, and practically all of the original surface has disappeared.

The road from Manatee to Sarasota, about 10 miles, was resurfaced in February, 1916, and treated with bituminous material. The surface was scarified and shaped, after which a 2-inch layer of lime rock was applied and rolled. By means of a pressure distributor from 0.5 to 0.6 gallon per square yard of bituminous materials was then applied and sanded. After about 10 days a second application of bituminous material consisting of from 0.2 to 0.3 gallon per square yard was applied and sanded. The road was treated to a width of 10 feet and the work done by contract at a cost of 39 cents per square yard, or a total cost of \$2,288 per mile. This, as with all other maintenance work of the county, was paid for out of the regular road funds.

The repair and maintenance work is done under the general direction of the county engineer and under the immediate direction of road overseers. There are 13 road overseers in the county, whose pay is \$3 per day for time actually employed. Laborers employed for patch and repair work receive \$1.50 per day. For use in this work the county owns a caterpillar tractor, 3 road graders, and 2 teams.

EFFECT OF ROAD IMPROVEMENT ON LAND VALUES.

It is difficult to determine what effect the road improvement has had upon the increase in assessed valuation of property in the county, but it might be well to compare the increase in valuation during the

period 1905 to 1910 and between the latter date and 1915, thus obtaining a 5-year period between which no roads were improved and a 5-year period during which the improved road system of the county was constructed. In 1905 the assessed valuation of all taxable property was \$2,074,016, while in 1910 it had increased to \$2,821,813, or 36 per cent. The assessed valuation in 1915 was \$8,085,100, a total increase of 180.5 per cent, so that the rate of increase was nearly six times as great as during the preceding 5 years. Comparing real estate only, it is shown that the assessed valuation was \$1,798,936 in 1905, \$2,492,232 in 1910, and \$7,338,050 in 1915. The increase was therefore 38.5 per cent from 1905 to 1910, and 194 per cent between 1910 and 1915. It is estimated that property is assessed at about one-third of its true cash value. The large 1915 assessment is due partly to the fact that until a few years ago property was assessed at only about 20 per cent of its value. A new railroad has been built in the county, and this, together with the improved highways, has resulted in bringing under cultivation large tracts of land which were formerly nonproductive.

A personal inspection to determine the effect of the road improvement on land values brought out the fact that there is a wide variation in land values, due partially to the relative fertility of the soil and partially to the transportation facilities. For example, the orange and grapefruit orchards, located on fertile "hammock" lands within easy hauling distance of the railroads or steamboat landings, are valued at from \$400 to \$600 per acre, while unimproved sandy pine lands within 3 miles of Manatee sell at from \$35 to \$40 per acre. Some of the low-priced lands had increased \$25 per acre, while uncleared pine land, which had sold during the preceding year at \$40 per acre, had increased in value to \$60 adjacent to the road and \$50 a mile from the road. As examples of values, it may be stated that a tract of 40 acres of land sold in 1911 for \$10 per acre was resold in 1912 for \$37.50 per acre. For another tract, which could have been bought in 1910 for \$20 per acre, \$100 per acre was refused in 1912. A tract of 1,000 acres 6 miles south of Manatee was purchased before the roads were improved at \$10 per acre, and where this land abutted on the improved roads it sold during 1913 for \$75 per acre, and for \$55 to \$60 per acre within one-half mile of the improved road.

A member of a real-estate firm of Bradentown stated that land which sold at \$20 per acre before the road improvement sold at \$50 per acre since the roads were constructed, and that lands were sold after the road construction which could not have been sold at any price before. Other examples illustrating the effect of the improved roads on land values are given, as follows:

A prominent citizen of Sarasota bought a tract of 29 acres about a year ago for \$10,000, or \$344 per acre, and resold April, 1914, for

\$15,000, or about \$517 per acre. A brick road is to be built by this place.

A tract of 40 acres one-fourth mile off Manatee-Sarasota Road (see Pl. XXXIV, fig. 2), 6 miles north of Sarasota, which was unsalable before the roads were improved, recently sold for \$2,600, or \$65 per acre.

Between Sarasota and Fruitville, along the improved road, a 10-acre tract was being held for \$2,500, or \$250 per acre.

On Manatee-Sarasota Road, about 2 miles south of Manatee, 15 acres of uncleared land was offered in 1913 for \$2,500, or \$166 per acre.

Another tract of 55 acres, $4\frac{1}{2}$ miles out of Bradentown, on the Palma Sola Road, which sold at the time of completion of the road for \$20 per acre, was again sold 2 years later without additional improvements for \$50 per acre. On the Palma Sola Road, about $5\frac{1}{2}$ miles from Bradentown, a tract containing 160 acres was originally set to grapefruit. When the road was improved the owner sold 40 acres for \$1,000, and this has since been subdivided and resold for over \$6,000.

A tract of a little more than 400 acres along the road from Ellenton to Parrish, about 2 miles above Ellenton and $1\frac{1}{2}$ miles off the road, recently sold for \$20 per acre. The same land was offered 2 years ago for \$10 per acre, but a purchaser could not be found.

Additional examples of the increased land values might be given, but the foregoing statements are sufficient to show that the increases have been remarkable and that the improvement of the roads has probably done more to bring this about than any other factor. From all of the information available it appears that there have been added from 50 to 100 per cent or at least \$15 per acre to the selling price of all lands within one-half mile of the new roads, a total of approximately \$611,000, which is more than twice the value of the bonds issued.

EFFECT OF ROAD IMPROVEMENT ON TRAFFIC.

To ascertain the volume of traffic on the improved roads and the relative cost of hauling before and after the roads were improved, information was obtained as to the farm production during the years 1912 and 1913. It was found that in 1912, 3,720 acres of land were devoted to the raising of vegetables and 4,950 acres were devoted to groves of citrus fruit in bearing. In 1913, while there had been no material increase in the citrus-fruit acreage, the area devoted to vegetables had increased to 5,195 acres. The yield of tomatoes alone during the season of 1913-14 was 450,000 crates or 11,250 tons. The yield of cabbage was 128,000 crates or 6,400 tons. Celery comprised 336,000 crates or 13,440 tons, and citrus fruits yielded a

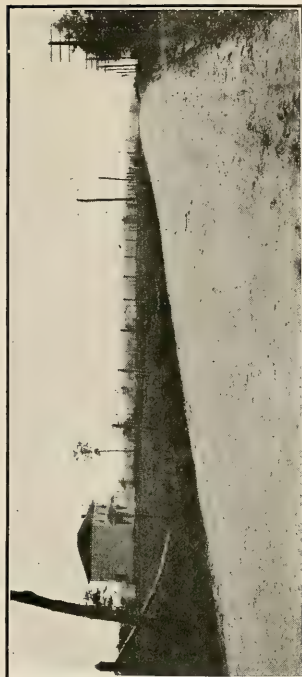
total of 1,000,000 crates or 40,000 tons. These four crops—tomatoes, cabbage, celery, and citrus fruits—for the season of 1913 comprised about 71,090 tons, to which miscellaneous vegetables and fruits added approximately 10,000 tons, making 81,090 tons of outgoing farm products. The average load on the old sandy roads was about 750 pounds for a one-horse team and about 1,500 pounds for a two-horse team, and the rate of wages was about \$4.50 to \$5 for a two-horse team and driver for a 10-hour day. The average haul over the old roads was approximately $2\frac{1}{2}$ miles, with a maximum of five trips per day, or about 10 ton-miles per day for each two-horse team, which made the cost of hauling approximately 45 cents per ton-mile. It was found that 4,800 pounds could easily be drawn by a 2-horse team after the roads were improved. In order to be entirely conservative, however, the average load on the improved roads is estimated at 3,500 pounds, the number of trips per day 5, the same as before the roads were improved, and the cost per day for team and driver \$4.50, the same as on the unimproved roads; the average haul $2\frac{1}{2}$ miles, the same as on the unimproved roads; and with these factors the average cost of hauling by a 2-horse team is about 20 cents per ton-mile, or a saving of approximately 25 cents per ton-mile, as compared with the hauling cost on the old roads.

Based upon information secured from railroad officials, local business men, and fruit and vegetable growers, it is estimated that about $33\frac{1}{2}$ per cent of the outgoing rail shipments, 85 per cent of the outgoing shipments by water, and 20 per cent of the incoming shipments pass over the improved roads. On this basis the annual traffic on the improved roads for 1915 was estimated to be 52,117 tons, or 130,292 ton-miles. If the saving of 25 cents per ton mile is applied to this amount it indicates an annual saving of \$32,573. As the tonnage increases from year to year the benefit of the improved roads in the way of reducing hauling costs will be more and more apparent, and there can hardly be a doubt that the investment will prove a profitable one.



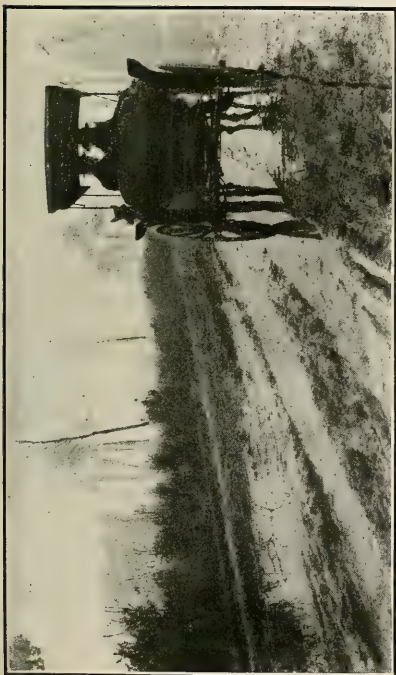
OPRRE 4986

FIG. 2.—COURTHOUSE ROAD, MARCH, 1911, SPOTSYLVANIA COUNTY, VA.
Clearing begun and house erected.



OPRRE 6691

FIG. 4.—COURTHOUSE ROAD, NOVEMBER, 1914, SPOTSYLVANIA COUNTY, VA.
Houses improved, note porch upon one; the farther one newly painted white; also see new fence.



OPRRE 3929

FIG. 1.—COURTHOUSE ROAD, MARCH, 1910, SPOTSYLVANIA COUNTY, VA.
Untbroken wilderness and no human habitation.



OPRRE 11753

FIG. 3.—COURTHOUSE ROAD, APRIL, 1912, SPOTSYLVANIA COUNTY, VA.
Land cleared and more houses built.



MAP OF SPOTSYLVANIA COUNTY, VA., SHOWING ROADS IMPROVED AND TO BE IMPROVED.



OPRRE 3538

FIG. 1.—COURTHOUSE ROAD, MARCH, 1910. BEFORE IMPROVEMENT.



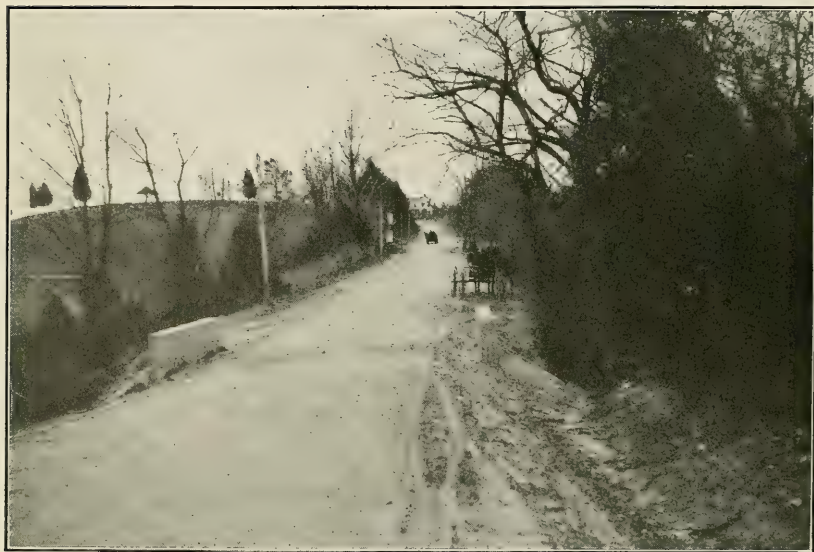
OPRRE 9221

FIG. 2.—COURTHOUSE ROAD, APRIL, 1913. GRAVEL, AFTER IMPROVEMENT.



OPRRE 6795

FIG. 1.—WOODEN BRIDGE FAILURE ON CHANCELLORSVILLE ROAD, MARCH, 1910, SPOTSYLVANIA COUNTY, VA.



OPRRE 6795

FIG. 2.—SAFE AND LASTING CONCRETE BRIDGE ON GRAVEL ROAD, SPOTSYLVANIA COUNTY, VA.

Same location as above, April, 1913.



OPRRE 3526

FIG. 1.—TRAFFIC ON COURTHOUSE ROAD, MARCH, 1910, SPOTSYLVANIA COUNTY, VA.

Load for 1 horse, 4 cross ties or 800 pounds.



OPRRE 10638

FIG. 2.—TRAFFIC ON COURTHOUSE ROAD, FEBRUARY, 1914, SPOTSYLVANIA COUNTY, VA.

Load for each horse about 2,000 pounds.



FIG. 1.—SCHOOL BUILDING AT SPOTSYLVANIA COURTHOUSE, MARCH, 1910, SPOTSYLVANIA COUNTY, VA.



FIG. 2.—THE OLD AND NEW SCHOOL BUILDINGS AT SPOTSYLVANIA COURTHOUSE, 1914, SPOTSYLVANIA COUNTY, VA.



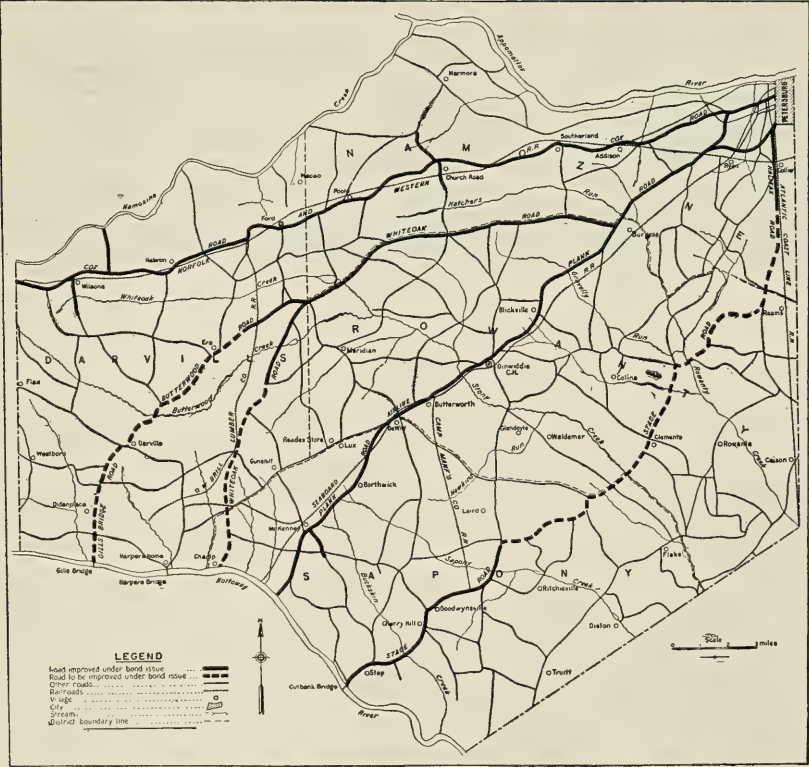
OPRE 3571

FIG. 1.—WHAT WAS CALLED BOYDTON PLANK ROAD IN MARCH, 1910, DINWIDDIE COUNTY, VA.

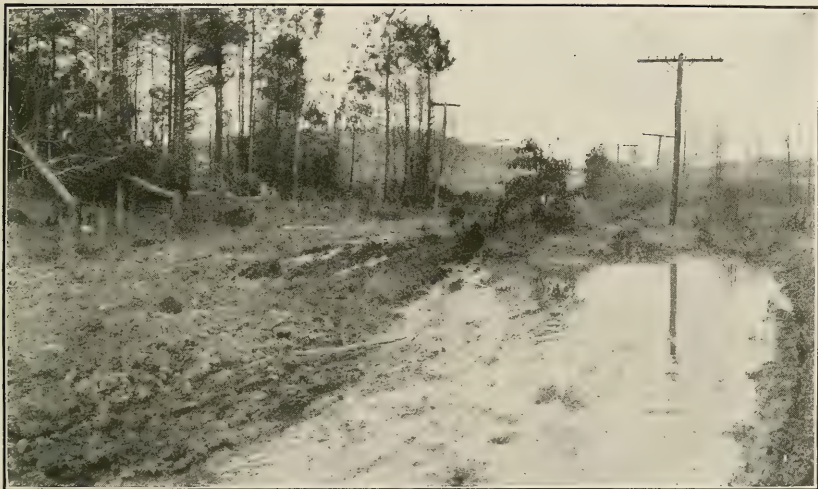


OPRE 6825

FIG. 2.—SAME SECTION AS ABOVE AFTER IMPROVEMENT, MARCH, 1912, DINWIDDIE COUNTY, VA.



MAP OF DINWIDDIE COUNTY, VA., SHOWING IMPROVED ROADS, 1915.



OPRRE 3587

FIG. 1.—A POORLY DRAINED SECTION OF THE COX ROAD, MARCH, 1910, DINWIDDIE COUNTY, VA.



OPRRE 5011

FIG. 2.—COX ROAD, SAME LOCATION AS ABOVE, MARCH, 1911. TOP SOIL, DINWIDDIE COUNTY, VA.



OPRRE 4978

FIG. 1.—TRAFFIC ON BOYDTON PLANK ROAD, MARCH, 1911, DINWIDDIE COUNTY, VA.
Load, 2 tons on each wagon.



OPRRE 7482

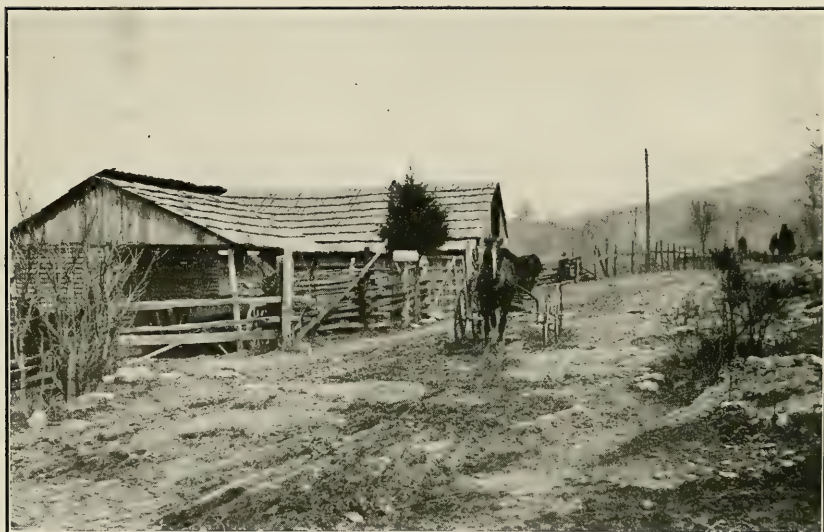
FIG. 2.—TYPE OF NEW STEEL BRIDGE ON BOYDTON PLANK ROAD, MARCH, 1912, DINWIDDIE COUNTY, VA.



FIG. 1.—CONSOLIDATED SCHOOLS, DINWIDDIE COURTHOUSE, DINWIDDIE COUNTY, VA.
Six rooms and auditorium. Cost \$6,000. Built since roads were improved.



FIG. 2.—SCHOOL WAGON WHICH CARRIES 20 CHILDREN FROM DEWITT TO DINWIDDIE COURTHOUSE, 6 MILES, MARCH, 1912, DINWIDDIE, VA.



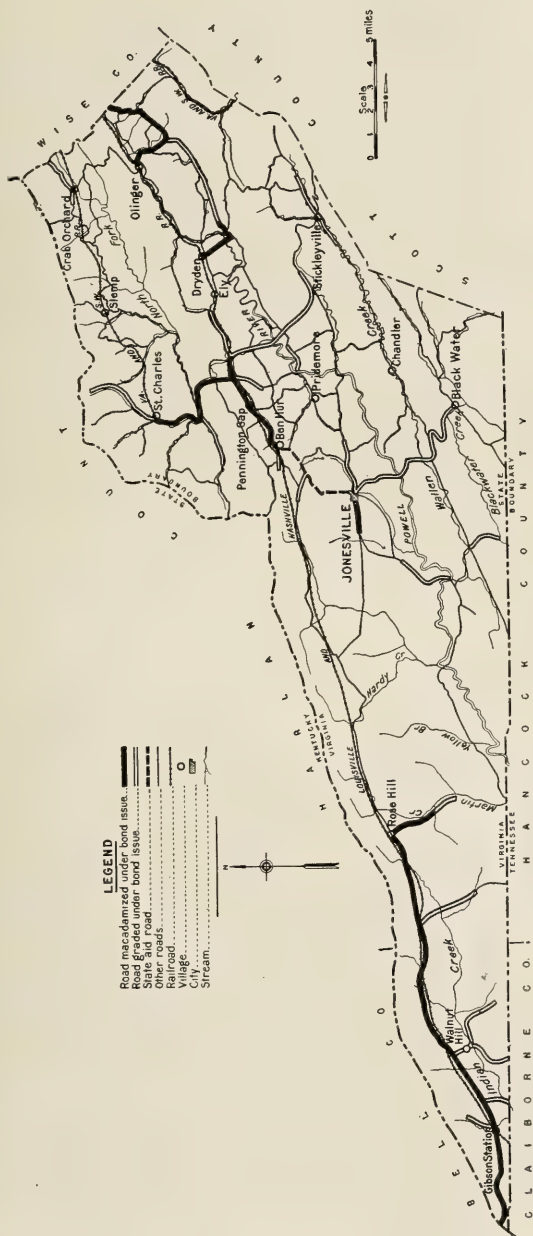
OPRRE 6165

FIG. 1.—ROAD NEAR OLINGER, MARCH, 1911, LEE COUNTY, VA.

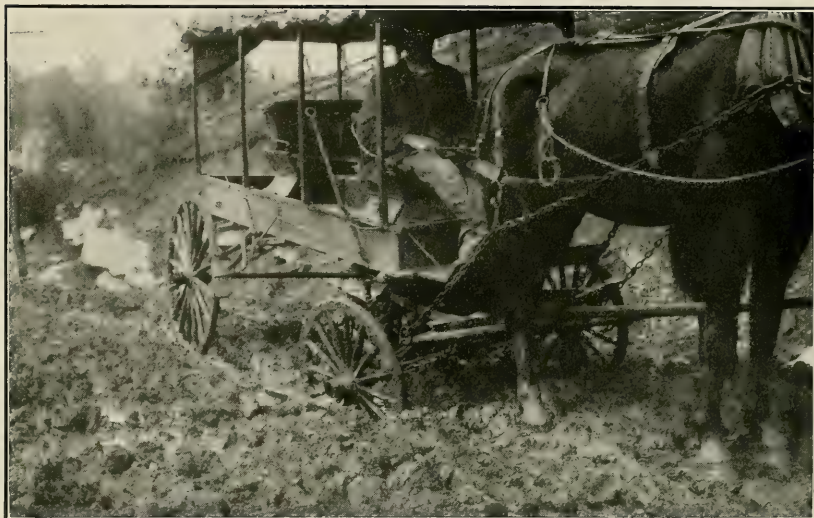


OPRRE 6825

FIG. 2.—ROAD NEAR OLINGER, MARCH, 1912, LEE COUNTY, VA.
Macadam. New schoolhouse in distance on left.



MAP OF LEE COUNTY, VA., SHOWING IMPROVED ROADS, 1915.



OPRRE 11208

FIG. 1.—THE HUB-DEEP BLACKWATER ROAD IN MARCH, 1911, LEE COUNTY, VA.



OPRRE 9793

FIG. 2.—THE BLACKWATER ROAD IN MAY, 1913. GRADED EARTH, LEE COUNTY, VA.



FIG. 1.—ROAD IN WHITE SHOALS DISTRICT, POWELLS VALLEY, LEE COUNTY, VA.

This county did not vote for a bond issue.

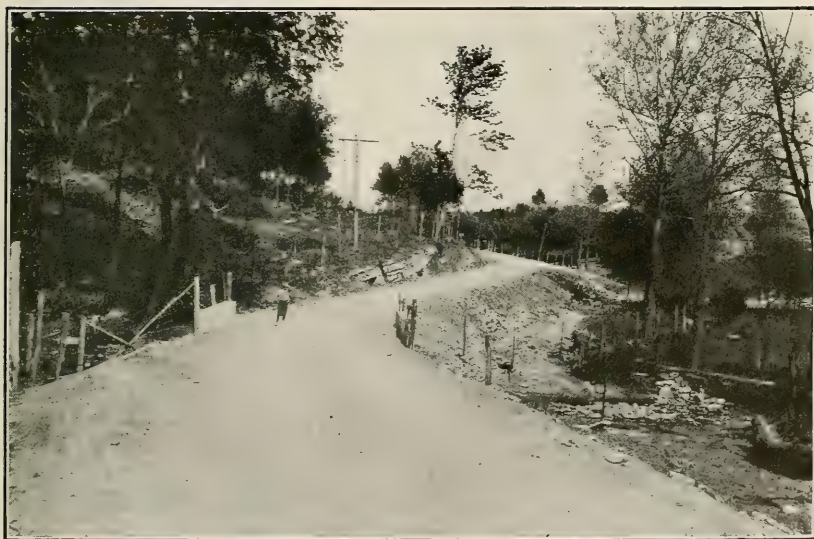


FIG. 2.—MACADAM ROAD IN ROSE HILL DISTRICT, POWELLS VALLEY, LEE COUNTY, VA.



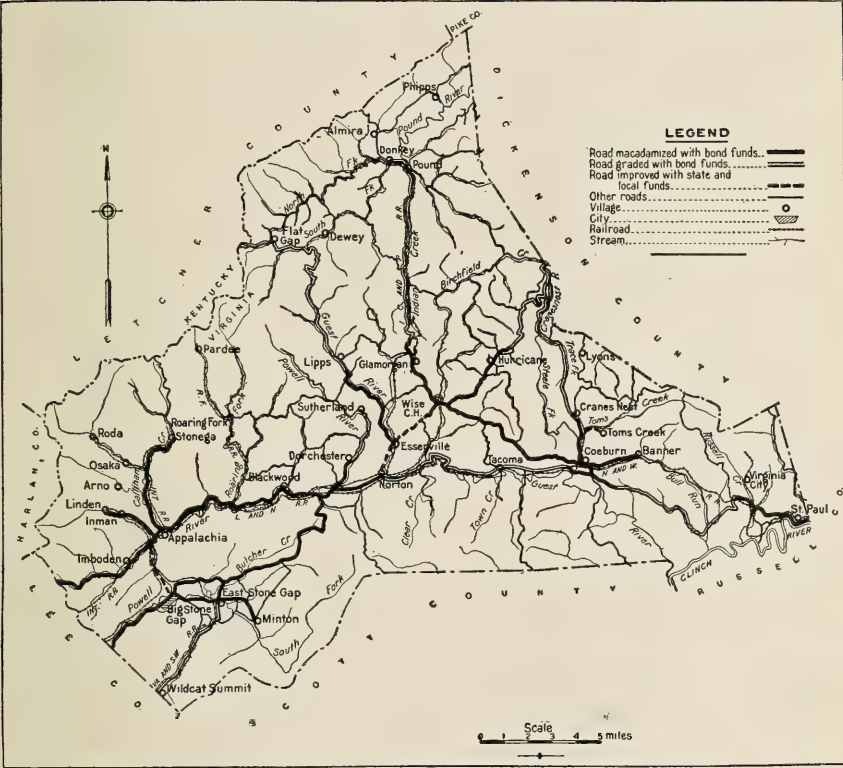
OPRRE 5153

FIG. 1.—BIG STONE GAP TO LEE COUNTY LINE. OLD LOCATION, MARCH, 1911, WISE COUNTY, VA.

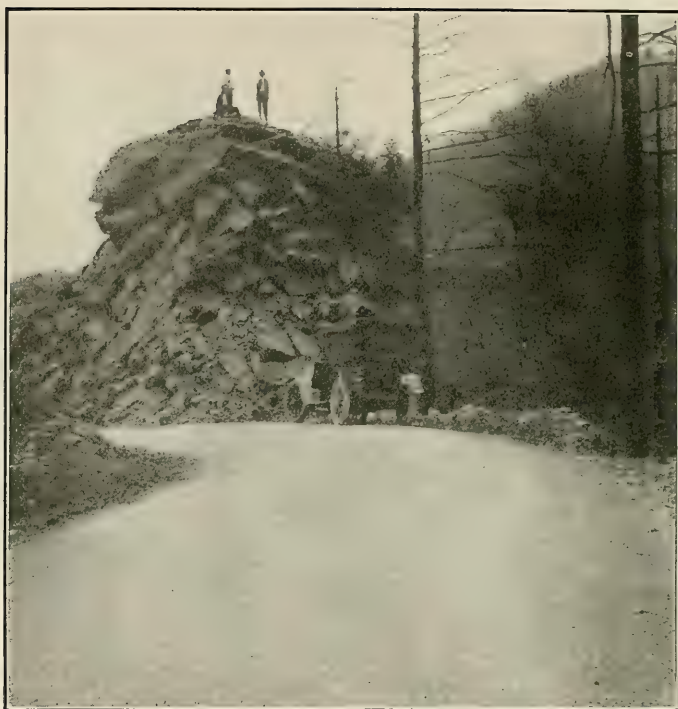


OPRRE 9828

FIG. 2.—BIG STONE GAP TO LEE COUNTY LINE. NEW LOCATION, MAY, 1913, WISE COUNTY, VA.



MAP OF WISE COUNTY, VA., SHOWING IMPROVED ROADS, 1915.



OPRRE 11246

FIG. 1.—STATE-AID ROAD BETWEEN BIG STONE GAP AND APPALACHIA,
WISE COUNTY, VA.



OPRRE 5012

FIG. 2.—NEW ROAD BETWEEN WISE AND COEBURN, MAY, 1913, WISE COUNTY, VA.



OPRE 14425

FIG. 1.—HURRICANE DISTRICT SCHOOL.



OPRE 14423

FIG. 2.—POUND DISTRICT SCHOOL.



OPRE 14424

FIG. 3.—THE HURRICANE AND POUND CONSOLIDATION INTO THE NEW HUTCHINSON GRADED SCHOOL, WISE COUNTY, VA.



OPRRE 9663

FIG. 1.—COUNTY ROAD, TOWN OF SANTA CLARA, IN THE ADIRONDACKS, MAY, 1913, FRANKLIN COUNTY, N. Y.



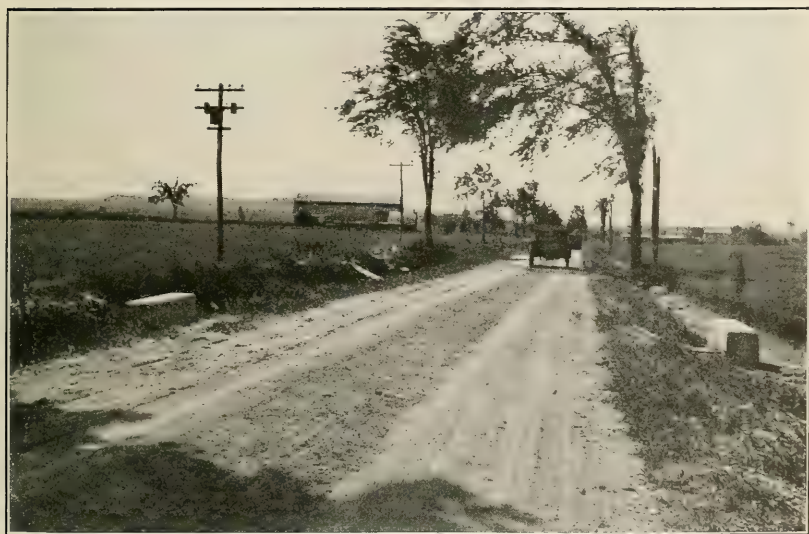
OPRRE 10998

FIG. 2.—COUNTY ROAD, MACADAM, SAME LOCATION AS ABOVE, MAY, 1914, FRANKLIN COUNTY, N. Y.



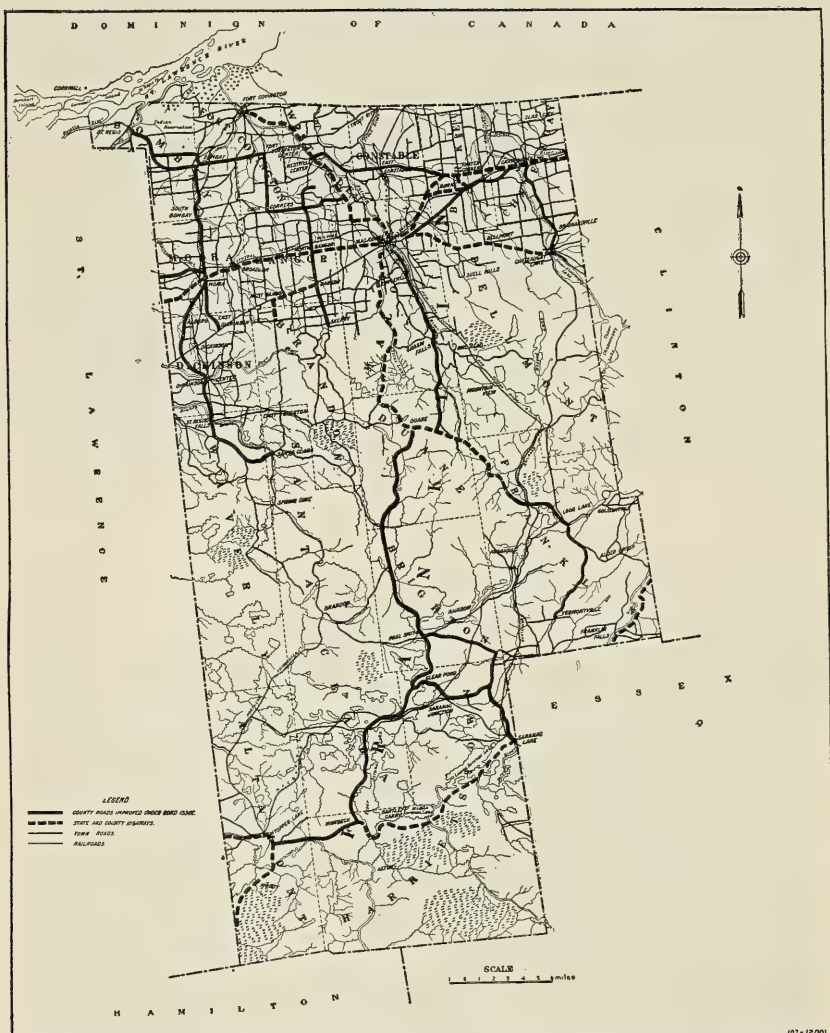
OPRRE T667

FIG. 1.—COUNTY ROAD, EARTH, TOWN OF BANGOR, MAY, 1912, FRANKLIN COUNTY, N. Y.



OPRRE 11015

FIG. 2.—COUNTY ROAD, MACADAM, SAME LOCATION AS ABOVE, MAY, 1913, FRANKLIN COUNTY, N. Y.



MAP OF FRANKLIN COUNTY, N. Y., SHOWING STATE AND COUNTY HIGHWAYS AND COUNTY ROADS.



OPRE 7692

FIG. 1.—TRAFFIC ON COUNTY ROAD BEFORE IMPROVEMENT, FRANKLIN COUNTY, N. Y.
Average load 10 cans of milk, 1,020 pounds.



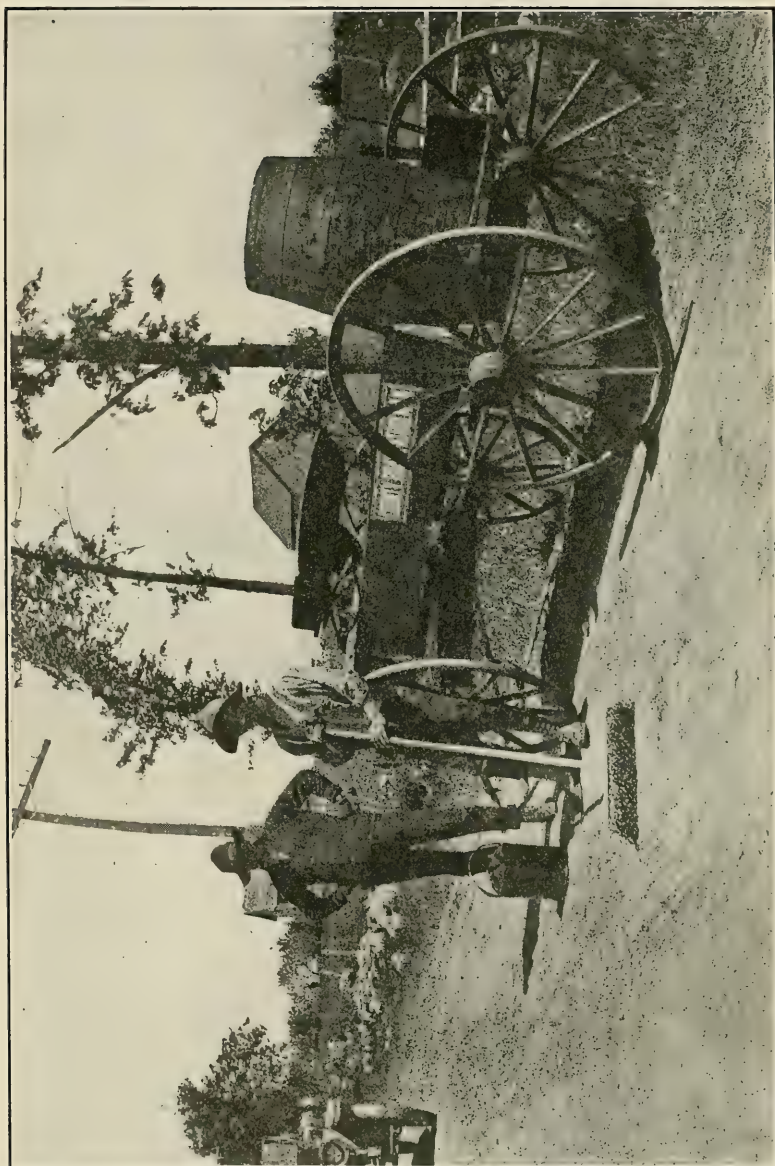
OPRE 10993

FIG. 2.—TRAFFIC ON TOWN ROAD AFTER IMPROVEMENT, FRANKLIN COUNTY, N. Y.
Maximum net load for four horses, 6,300 pounds.



OPRE 11014

FIG. 3.—AUTOMOBILE TRUCK TRAFFIC ON COUNTY ROAD AFTER IMPROVEMENT,
FRANKLIN COUNTY, N. Y.
Maximum net load 50 cans of milk, 6,000 pounds.



OPRRE 11096

COUNTY PATROLMEN, FRANKLIN COUNTY, N. Y.

Each patrolman has from 2 to 8 miles of road, receives \$3 per day, and is employed when needed.



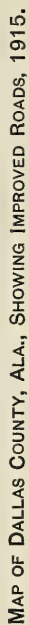
OPRRE 10860

FIG. 1.—SUMMERFIELD ROAD, 8½ MILES FROM SELMA, DALLAS COUNTY, ALA.
General condition of entire road before improvement.



OPRRE 10887

FIG. 2.—SUMMERFIELD ROAD AFTER IMPROVEMENT WITH GRAVEL, DALLAS COUNTY, ALA.





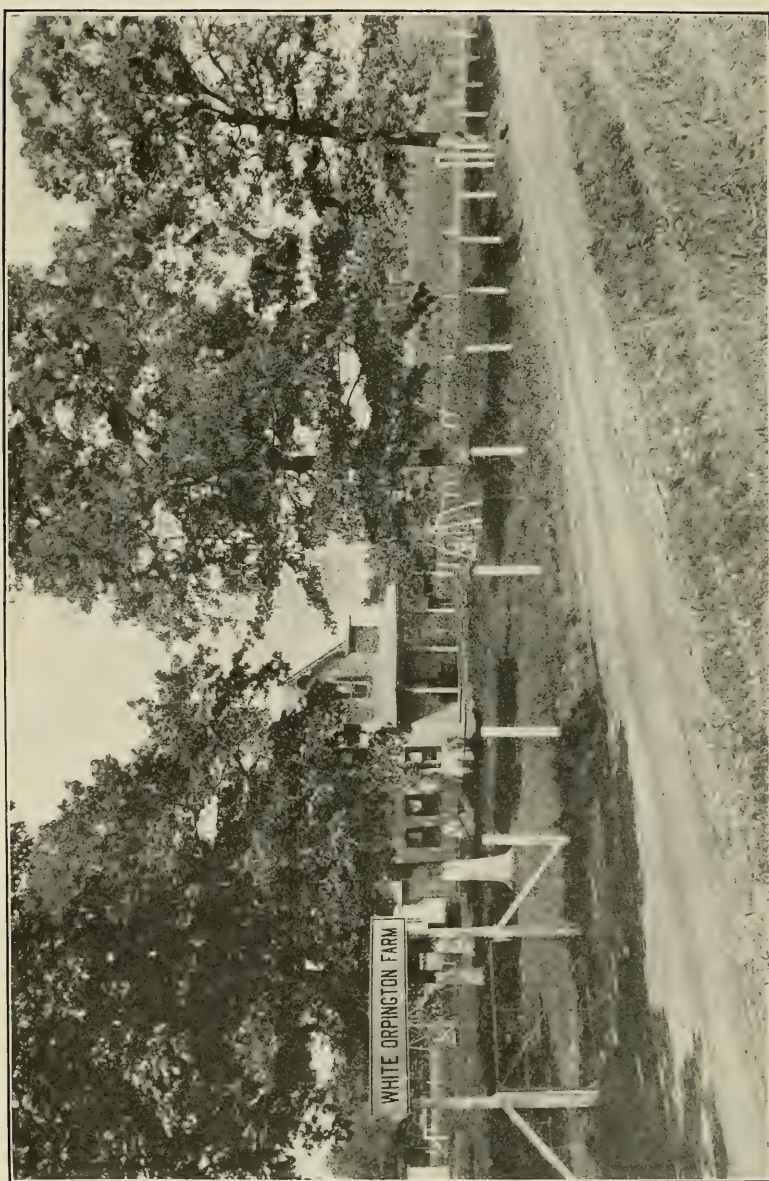
OPRRE 4912

FIG. 1.—BURNSVILLE ROAD, OLD LOCATION, DALLAS COUNTY, ALA.



OPRRE 9345

FIG. 2.—BURNSVILLE ROAD, NEW LOCATION, SURFACED WITH GRAVEL, DALLAS COUNTY, ALA.



OPPRE 8118

A NEW INDUSTRY ON THE MARION JUNCTION ROAD, DALLAS COUNTY, ALA.



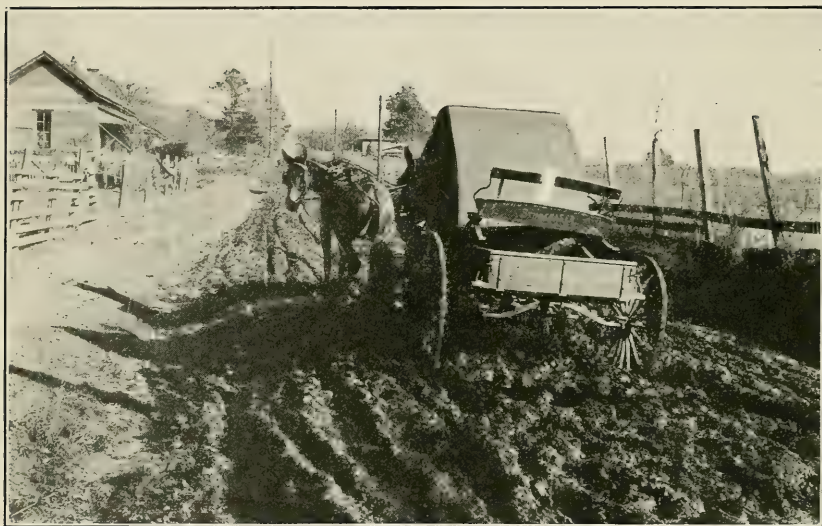
OPRRE 7045

FIG. 1.—BONITA ROAD, FEBRUARY, 1912, LAUDERDALE COUNTY, MISS.



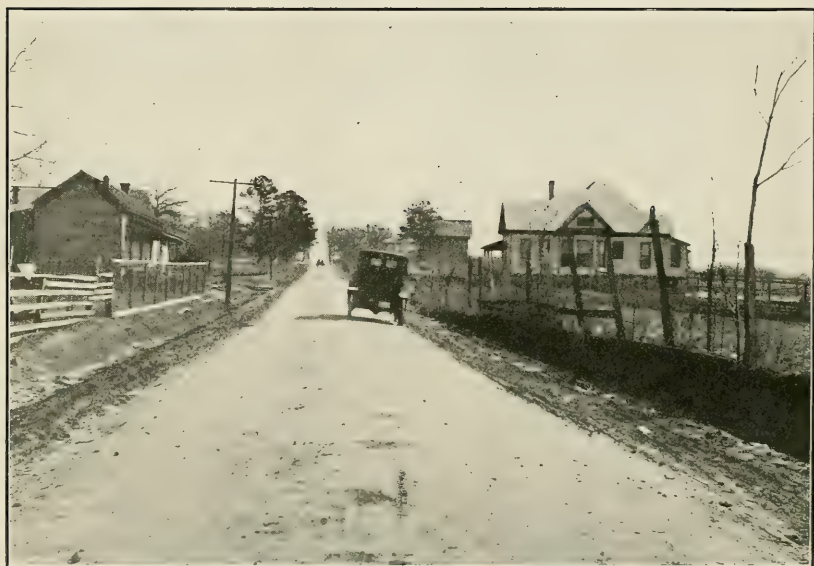
OPRRE 8751

FIG. 2.—BONITA ROAD, MARCH, 1913, GRAVEL-MACADAM, LAUDERDALE COUNTY, MISS



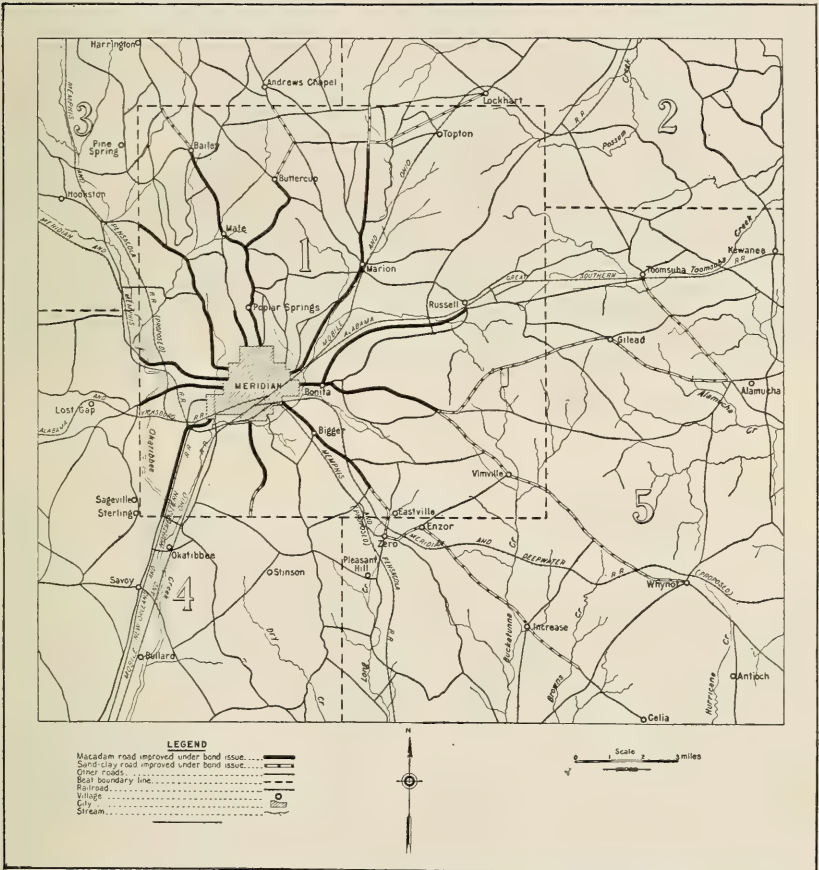
OPRRE 7044

FIG. 1.—BONITA ROAD, FEBRUARY, 1912, LAUDERDALE COUNTY, MISS.



OPRRE 8752

FIG. 2.—BONITA ROAD, MARCH, 1913, GRAVEL-MACADAM, LAUDERDALE COUNTY, MISS.



MAP OF PART OF LAUDERDALE COUNTY, MISS., SHOWING IMPROVED ROADS, 1915.



OPRRE 7042

FIG. 1.—CAUSEYVILLE ROAD, FEBRUARY, 1912, LAUDERDALE COUNTY, MISS.



OPRRE 8736

FIG. 2.—CAUSEYVILLE ROAD. SAME LOCATION AS ABOVE, GRAVEL-MACADAM SURFACE, FEBRUARY, 1913, LAUDERDALE COUNTY, MISS.



OPRE 7043

FIG. 1.—BONITA ROAD, FEBRUARY, 1912, LAUDERDALE COUNTY, MISS.

A merchant paid \$25 per 100 pounds for 4-mile haul, or \$1.25 per ton-mile, and postoffice authorities paid \$12.50 per day per 1 day's mail delivery a few days before this photograph was taken.



OPRE 8754

FIG. 2.—BONITA ROAD, GRAVEL-MACADAM. SAME LOCATION AS ABOVE, MARCH, 1913, LAUDERDALE COUNTY, MISS.



OPRRE 5120

FIG. 1.—MANATEE-SARASOTA ROAD, MANATEE COUNTY, FLA., IN 1911.



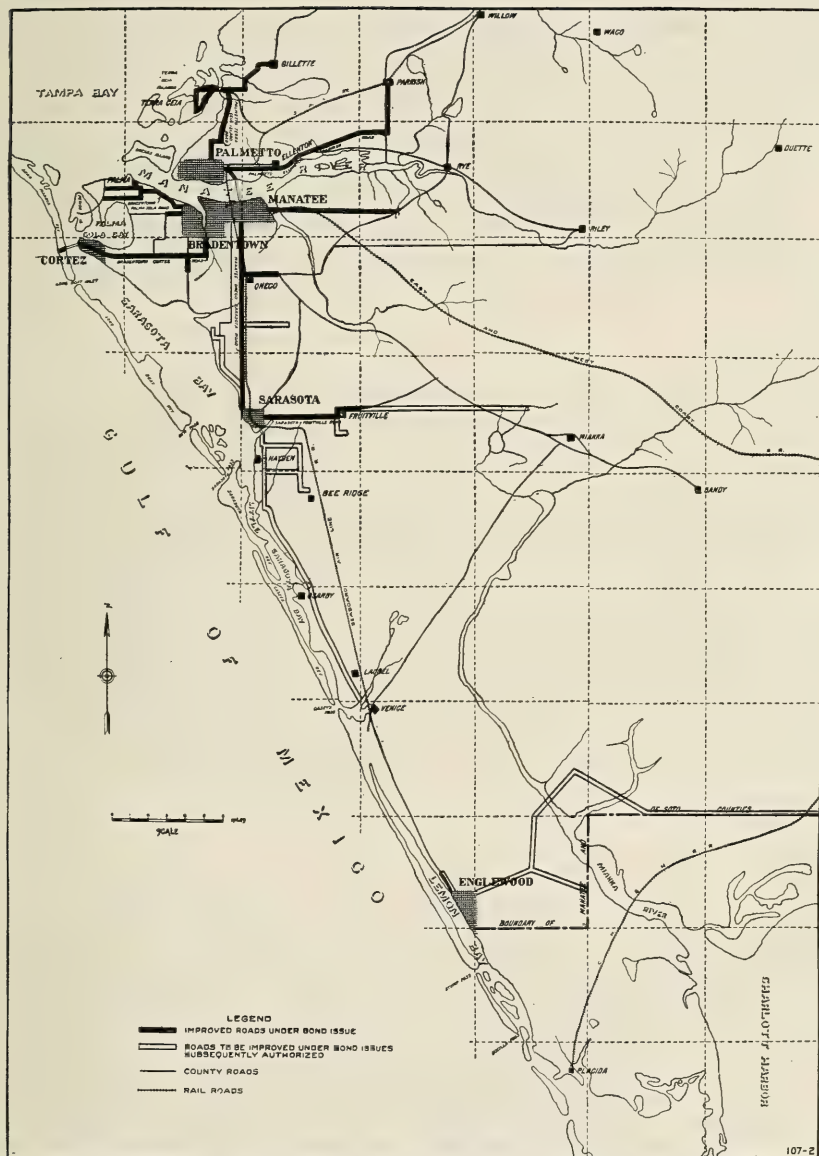
OPRRE 5415

FIG. 2.—MANATEE-SARASOTA ROAD IN 1912.



OPRRE 5119

FIG. 3.—TRAFFIC FROM MANATEE-SARASOTA ROAD. NET LOAD 45 CRATES OF CELERY,
2,600 POUNDS.



MAP SHOWING THE MARKET ROAD SYSTEM, MANATEE COUNTY, FLA.

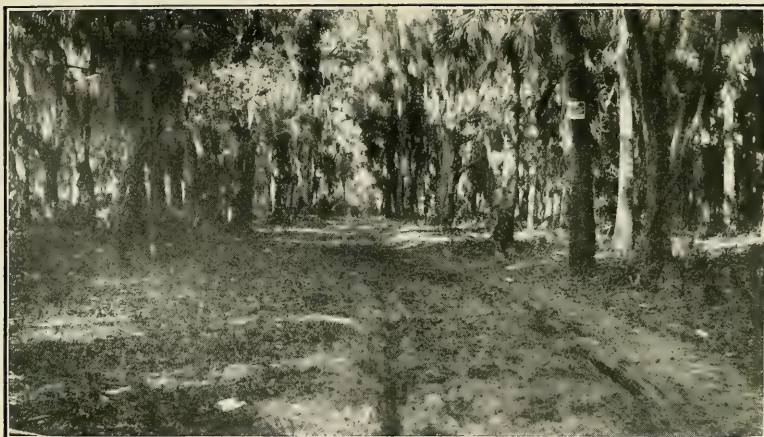


FIG. 1.—ELLETON-BELK ROAD, 1911.

OPRE 5103

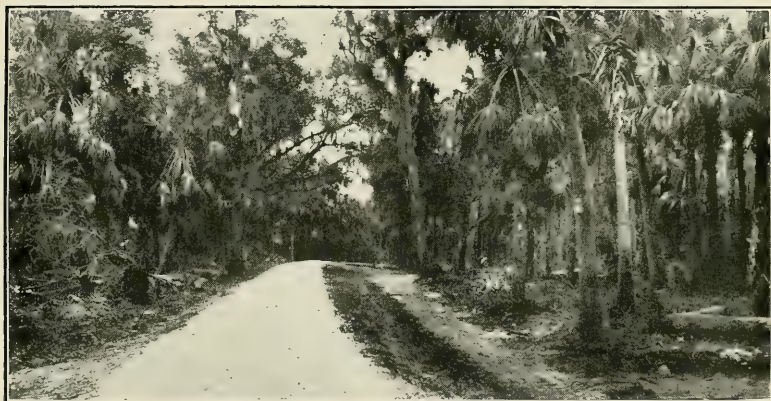
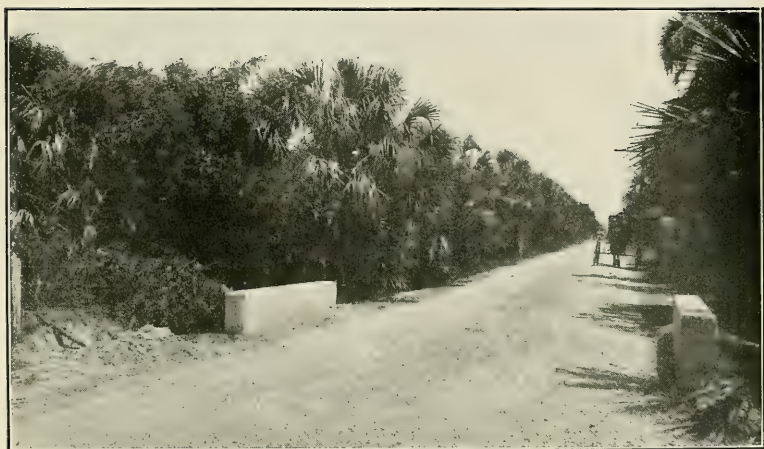


FIG. 2.—ELLETON-BELK ROAD, 1912. SHELLS.

OPRE 5443



OPRE 5224

UNITED STATES DEPARTMENT OF AGRICULTURE



BULLETIN No. 394



Contribution from Office of Markets and Rural Organization
CHARLES J. BRAND, Chief

Washington, D. C.

November 3, 1916

A SURVEY OF TYPICAL COOPERATIVE STORES IN THE UNITED STATES.

By J. A. BEXELL, *Dean, School of Commerce, Oregon Agricultural College*; HECTOR MACPHERSON, *Director, Bureau of Markets, Oregon Agricultural College*; and W. H. KERR, *Investigator in Market Business Practice, Office of Markets and Rural Organization, United States Department of Agriculture.*

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Operating organization.....	8	The balance sheet.....	20
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THE PURPOSE, SCOPE, AND METHOD OF THE SURVEY.

The financial success of the Rochdale Cooperative Store in Great Britain, as well as in several other European countries, notably Denmark and Switzerland, has aroused a widespread interest in that type of cooperation in the United States. This interest has resulted in the establishment of stores in all parts of the country, until it is estimated that there are now approximately 400 in the United States, distributed mainly in the North Central States and on the Pacific coast.

The movement has probably been stimulated by investigations carried on by the governments of various cities and States which have emphasized the cost of distribution as the chief factor in the high cost of living. The Department of Agriculture, as well as the various universities, agricultural colleges, and departments of state have received appeals for information regarding the feasibility of the cooperative store as a remedy for the great expense of distribution and the resulting high cost of living.

With a view to obtaining some definite information on this subject, the Office of Markets and Rural Organization, in cooperation with the School of Commerce of the Oregon Agricultural College, during

NOTE.—This bulletin should be of interest to cooperative stores and to producers and consumers generally.

the summer of 1915, undertook to make a survey of a number of typical cooperative stores. The sole purpose of the survey was that some disinterested agency might be informed as accurately as possible regarding the subject of cooperative stores, and that some measure of guidance might be extended to stores which are now operating and to those which may be formed in the future.

No attempt was made to visit or question all the cooperative stores in any State visited. The investigation was confined to a number of representative stores which were chosen after a study of all available information. Care was taken to include as nearly as possible representatives of all existing types. Among them are found some of the most successful concerns, as well as others which, at the time of the survey, had already gone into the hands of receivers. A study of the tables makes clear the great range of stores investigated. The stores selected were in 10 different States: Michigan, Illinois, Wisconsin, Minnesota, North Dakota, Iowa, Kansas, California, Oregon, and Washington.

A list of questions, arranged in groups, was drawn up as shown on page 3. The investigator made a personal visit to each store, went over the entire list of questions with the manager, and supplemented the questionnaire by notes on points which could not be covered in this categorical form.

The present bulletin covers the material collected from 60 stores, but almost half of these were unable to supply sufficiently accurate data to be included in Table X. For the most part, the tables are allowed to speak for themselves. The supplementary reading matter is intended merely to bring out facts which either can not be included in the tables or which might escape the attention of the student if specific reference were not made to them. In the questionnaire (p. 3) the figures represent averages for the stores answering the question, which number is indicated in parentheses. The results may be studied to better advantage by reference to the different tables.

At the outset it must be made clear that neither the tables nor the observations make any pretense of finality. At the same time, it is believed that they are sufficiently reliable to offer timely suggestions to all who are interested in the cooperative-store movement. The investigator used as much precaution to obtain accurate data as the limitations of the survey would permit. Nearly all of the results are based on certified reports. In a few instances careful estimates were accepted: but these, it is believed, in no case materially affect

NOTE.—For further discussion of cooperative purchasing of farm supplies see Carver, T. N.: *The Organization of a Rural Community*, Department of Agriculture Yearbook, 1914 (separate 632), and Bassett, C. E.: *The Cooperative Purchase of Farm Supplies*, Department of Agriculture Yearbook, 1915 (separate 658).

the results. Where such estimates appear doubtful they have been eliminated. This accounts in part for the varying number of associations answering the different questions.

For obvious reasons care has been taken to conceal both the identity and locality of the stores investigated. The numbers in Table 10 bear no relation to the order in which the stores were visited nor to the numbers on the questionnaires. Stores which had been recently established and which had as yet little or no experience of value were usually omitted. Almost without exception the investigator found the store managers willing to cooperate in attaining the object of the survey and glad to furnish all the information in their possession.

ORIGIN OF THE STORES.

Inquiry into the origin of the stores investigated revealed a variety of causes. In some cases the stores were started as a protest against real or fancied abuses. In others the association was organized on the initiative of outside promoters who make a business of organizing cooperative stores. In still other cases there is reason to believe the stores were established on the initiative of individuals who expected to obtain permanent employment in the store.

As will be noticed by the answers to questions 6 and 7, there were 20 cases in which an established business was purchased. A great deal has been said in favor of this practice. It has certain advantages, to be sure, but from the cases examined in the present survey the advantages of the established business appear to have been offset by serious disadvantages. In some instances failing concerns succeeded in unloading stocks of goods upon the cooperative association at excessively high prices and with liberal allowances for good will thrown in. In other cases the association found itself with a large proportion of the purchased stock either shelf worn or poorly adapted to the needs of the community.

QUESTIONNAIRE ON THE BUSINESS PRACTICE OF COOPERATIVE STORES.¹

Report No. _____.

Date _____, 1915.

Information obtained by _____. Information given by _____.

I. General:

1. Name: ____; 2. City: ____; 3. Street and No. ____; 4. County: ____;
5. State: ____; 6. Was new business started: (20) Yes; 7. Established business purchased: (20) Yes; 8. Principal line: ____;
9. Secondary lines: ____; 10. Principal industry in locality: (31) Farming; 11. Is location desirable: (37) Good; 12. Present manager: ____; 13. His experience: ____.

¹ Numbers in parentheses are stores reporting. In most cases the difference between the number given and 60, the total number surveyed, were either answered in the opposite or not at all. Where not qualified figures represent averages.

II. *External or corporate organization:*

14. Organized under cooperative law: (32) Yes; 15. Corporation law: (10) Yes; 16. Number of members (43) 228; 17. Condition of membership: ----; Vote: (40) One per member; 19. Principal nationality of members (49) American born; 20. President: (46) Yes; 21. Vice president: (35) Yes; 22. Secretary: (38) Yes; 23. Treasurer: (34) Yes; 24. Auditors (24) Yes; 25. Other officers: ----; 26. Directors: (43) 5; 27. Term of office: (34) One year; 28. Committees and duties: ----; 29. Branches: (5) Yes; 30. Controlled by grange: (2) Yes; 31. Controlled by farmers' union: (1) Yes.

III. *Internal or operating organization:*

32. General manager: (47) Yes; 33. Sales manager: (7) Yes; 34. Buyer: (4) Yes; 35. Cashier: (10) Yes; 36. Bookkeepers: (31) Yes; 37. Salesmen: (44) 5; 38. Saleswomen: (28) 3; 39. Stenographers: (3) Yes; 40. Departments: (49) 2; 41. Is responsibility definite: (27) No.

IV. *Finance:*

42. Capital authorized: (32) \$45,437; 43. Subscribed: (41) \$20,143; 44. Paid in: (50) \$16,627; 45. Par value of shares: (44) \$53; 46. How transferable: ----; 47. Amount may be held by member: (31) High \$8,000, low \$10, average \$1,200; 48. Interest paid on stock: (37) Yes; 49. Paid annually: (34) Yes; 50. Semiannually: (40) No; 51. Dividends to members: (35) Yes; 52. Dividends to nonmembers: (18) Yes; 53. Dividends paid annually: (30) Yes; 54. Semiannually: (39) No; 55. Dividends paid in cash: (27) Yes; 56. Dividends in merchandise: (29) No; 57. Dividends in stock: (35) No.

V. *Credit:*

58. Do you borrow money: (40) Yes; 59. Rate of interest: (37) 7 per cent; 60. Are bills discounted regularly: (18) Yes; 61. Estimated saving: (24) \$997; 62. Is credit difficult to obtain: (33) No; 63. Security offered: (26) None; 64. Credit extended to customers: (45) Yes; 65. For how long: (27) Two months; 66. Losses due to credit: (15) \$664; 67. Are accounts paid promptly: (25) Yes; 68. Advantages of credit: ----; 69. Disadvantages: ---- (For per cent credit sales, see question 86.)

VI. *Purchasing:*

70. Principal market: ----; 71. From salesmen: (43) Yes; 72. From catalogue houses: (21) No; 73. From manufacturers: (24) Yes; 74. Are lowest prices obtained: (27) Yes; 75. Estimated produce bought from farmers: (22) \$12,126; 76. Are all orders reduced to writing: (30) No; 77. Invoices checked systematically: (39) Yes; 78. Difficulties: ----.

VII. *Selling:*

79. Per cent country trade: (43) 63; 80. Per cent town trade: (43) 37; 81. Per cent membership trade (42) 60; 82. Nonmembership trade: (42) 40; 83. Per cent active members (37) 80; 84. Nonactive: (37) 20; 85. Per cent cash sales: (36) 50; 86. Per cent credit sales: (36) 50; 87. Advertising methods: (23) None; 88. Delivery system: (32) Yes; 89. Total annual sales by departments: (45) \$87,781; 90. Rate of profit on sales by departments: (36) 20 per cent;¹ 91. Store opens: (37) 7 a. m.; 92. Closes: (37) 7 p. m.; Saturdays 9 to 10.

¹ This is the estimate made by managers (see also Table 10).

VIII. Accounting and business methods:

93. When was system adopted: ----; 94. Satisfactory: (20) Yes; 95. Defects: ----; 96. Double entry: (36) Yes; 97. How often is trial balance taken: (36) Monthly; 98. Is total cash deposited daily: (28) No; 99. Sales slips used: (42) Yes; 100. Are trading coupons used: (27) No; 101. Is duplicating billing ledger used: (32) No; 102. Are cost accounts kept by departments: (34) No; 103. System of filing sales slips: ----.

IX. Reports and auditing:

104. Manager's report: (20) Monthly; 105. Contents: ----; 106. Form: ----; 107. When is report presented: ----; 108. Are audits made regularly: (34) Yes; 109. How often: (11) Monthly; 110. By committee: (21) Yes; 111. Cost: ----; 112. By professional auditor: (26) No; 113. Cost: (15) \$56; 114. Auditor's report includes: ----; 115. Are members competent: (27) No.

X. Mechanical equipment:

116. Cash register: (39) Yes; 117. Customers' account file: (23) No—(20) Yes; 118. Typewriter (25) Yes; 119. Adding machine: (24) Yes; 120. Filing equipment: (29) Yes; 121. Overhead carrier: (34) No; 122. Check protector: (26) No; 123. Mimeograph: (39) No; 124. Addressograph: (41) No; 125. Other equipment: ----.

XI. Business forms:

126. Constitution and by-laws: ----; 127. Annual report: ----; 128. Stock certificate: ----; 129. Membership certificate: ----; 130. Membership register: ----; 131. Stock ledger: ----; 132. Purchase requisition: ----; 133. Order for goods: ----; 134. Settlement memorandum: ----; 135. Duplicating sales slip: ----; 136. Triplicating sales slip: ----; 137. Customers' ledger: ----; 138. Billing ledger: ----; 139. Credit memorandum: ----; 140. Credit rating blank: ----; 141. Cash sales ticket: ----; 142. Business summary: ----; 143. Cash receipts distribution: ----; 144. Cash payments distribution: ----; 145. Check, ordinary form: ----; 146. Voucher check: ----; 147. Double entry ledger: ----; 148. Journal: ----; 149. Purchase register: ----; 150. Sales register: ----.

XII. Comments on accounting system:**XIII. Resources:**

151. Cash: (46) \$2,074.78; 152. Merchandise inventories: (46) \$18,049.41; 153. Equipment: (46) \$1,640.21; 154. Accounts receivable: (46) \$7,386.05; 155. Bills receivable: (46) \$2,070.76; 156. Real estate: (46) \$3,550.54; 157. Miscellaneous¹ (46) \$2,092.58; 158. Total: (46) \$26,864.33.

XIV. Liabilities:

159. Capital stock: (46) \$15,947.67; 160. Accounts payable: (46) \$5,056.09; 161. Bills payable: (46) \$5,151.87; 162. Surplus: (46) \$4,353.10; 163. Undivided profits: (46) \$5,182.74; 164. Unpaid dividends: (46) \$192.28; Miscellaneous:¹ (46) \$980.58; 166. Total: (46) \$36,864.33.

¹ Miscellaneous includes such items as interest, prepaid insurance, prepaid rent, and unpaid labor.

XV. Summary of overhead expenses:

167. Salaries and labor: (31) \$4,695.93; 168. Rent: (23) \$881.51; 169. Light and heat: (16) \$137.14; 170. Insurance: (30) \$301.81; 171. Taxes: (21) \$283.69; 172. Telephone and telegraph: (8) \$43.44; 173. Interest: (25) \$587.83; 174. Postage and stationery: (5) \$174.89; 175. Miscellaneous (36) \$5,417.29; Total: (41) \$9,609.27; 177. Net profit for last year: (31) \$5,749.33; 178. Net per cent profit: ----; 179. Per cent on capital, including surplus and undivided profits: ----.

XVI. Monthly salaries:

180. President: ----; 181. Secretary: ----; 182. Treasurer: ----; 183. Manager: (42) \$106; 184. Bookkeeper: (27) \$68.87; 185. Cashier: ----; 186. Head salesman: (31) \$74.13; 187. Other salesmen: (31) \$49.95; 188. Saleswomen: (26) \$32.10; 189. Extra labor: ----; 190. Total: ----.

XVII. Comments:

191. Is the business in satisfactory condition: (32) Yes. 192. Has the business been reorganized: (37) No; 193. Why: ----; 194. Expansion planned: (30) No; 195. Educational propaganda: (30) No; 196. Probable future: (20) Bright¹; 197. Effect on service to the patrons: ----; 198. Effect on local commodity prices: ----; 199. Effect on the community: ----; 200. Cooperation with other merchants: (33) No; 201. How do expenses compare with private business in town: (12) Same; 202. Are employees members: (24) No; 203. Do they share in profits: ----; 204. Which employees are bonded: ----.

GENERAL ORGANIZATION.

Owing to the fact that the enactment of cooperative laws in the different States is a comparatively recent movement, a large proportion of the stores examined were originally established under the ordinary corporation laws. Most of them, however, are now organized under cooperative laws. At the time of this survey such laws had been enacted by 30 States, including all of the States covered by this study. Thirty-two out of 42 of the stores reporting on questions 14 and 15 were then organized under special cooperative laws. Those which still retained the corporate form of organization adhered to certain cooperative principles which were made a matter of agreement between the members through their constitution and by-laws. For example, 40 of the stores had adopted the principle of 1 man, 1 vote; while 5 of them adhered to the plan of voting according to investment. It was noticed, however, that in the older associations established under the corporate law there was a tendency for the stock to pass into a few hands, and in several of these cases the store was cooperative only in name.

An attempt was made to compile a table showing the size and financial success of stores on the basis of nationality, occupation, and

¹ This is the opinion of the managers.

religion of those participating. Although the figures were not conclusive, nor sufficient for tabular presentation, they seemed to bear out the opinion of many of the managers that a cooperative store is apt to be more successful in a community which is made up of people of one nationality. Similarly, in industrial communities, it was found that stores are more successful where a large percentage of the membership is of the same occupation; and at least one case was observed in which common church affiliation is the basis of successful cooperation.

The membership ranges from 1,600 to 30, while the average for all the stores surveyed was 228. Although there were some notable exceptions, as a general rule it was found that the success of the stores was almost in direct proportion to the membership. This may be due to the fact that the well-managed store usually has little difficulty in increasing its membership, while the poorly managed store soon loses the support of the members with which it begins operation.

It was surprising to find so small a proportion of the stores controlled by farmers' organizations, such as the Grange and the Farmers' Union. As a matter of fact, the farmers' organizations have taken the initiative in starting many stores, but not finding themselves strong enough to support the business out of their own membership, they have thrown the conditions of membership open. Even where such stores have been successful, they have frequently had a bad effect upon the farmers' organization. In some cases the farmers, expecting great things from their store, have allowed the local farmers' organization to fall into decay, claiming that the store was all the organization they required. In other cases, where the store fathered by a farmers' organization has been a failure, the effect has been even more disastrous to the association.

The survey brought out the fact that the location has a great deal to do with the success of the store. The best location, however, is not always synonymous with the most expensive or most central location. Much depends upon the type of trade. In the case of stores dependent largely upon country trade the proximity of horse sheds and hitching facilities is an advantage. Such conveniences usually can not be had in an expensive central location. On the other hand, there are instances which tend to show that the store should not be located too far from the points where country roads converge.

Five of the stores studied had undertaken the establishment of branches in outlying districts. Almost without exception, the policy of establishing such branch stores was found to be unsatisfactory. In all cases the branches were found to be a heavy drain on the working capital of the parent store. It was also found that the members in the branch district were inclined to rely for success upon the parent association, thus weakening the branch. It appeared, too,

that the average manager secured by cooperative stores lacks the business ability necessary for the management of more than one store. Hence, although the policy of establishing branches is right in principle, as shown in numerous cases under private and corporate management, notably the well-known chain stores, the results of this survey would indicate that a cooperative store should consider the matter with the greatest care before undertaking the establishment of branches.

It will be noticed that most of the stores have the usual officers and board of directors. The most common number of directors is 5 and the usual term of office is 1 year. Questions directed upon this policy seem to indicate that the 1-year term does not give sufficient stability of policy. Of course, it frequently happens that old directors are reelected; but in many instances new directors are elected at the end of each year, and it is stated that by the time they leave office they are just beginning to gain the experience necessary in order to be of real value to the association. In the case of one of the most successful stores many of the officers and directors had served for over 20 years, and the by-laws provided that only one-third of the directors should be elected annually. Even if new directors were elected, which did not often happen, at least two-thirds of the board were always made up of experienced men. It was found that in some associations the president was elected directly by the members and was ex officio member of the board of directors. In the majority of cases, however, he was elected by the members of the board from among their number. It would appear that on the whole the latter plan makes for greater efficiency.

It is a common practice for the by-laws to provide an auditing committee of two or three, to be elected from among the membership at its annual meeting. More rarely the auditors are appointed by the board of directors. The experience gained by those making the survey leads to the conclusion that the auditing committee should act as a connecting link between the membership and the management, keeping check at all times upon the business practice of the association and counseling the directors whenever the condition of the business appears to demand special attention. This would indicate that the auditing committee should be elected by the members at their annual meeting and be made directly responsible to them.

As will be more fully discussed in a later section, the results of the survey bring out very clearly that one of the greatest weaknesses of cooperative stores lies in the lack of thoroughness in their audits.

OPERATING ORGANIZATION.

The business organization of a cooperative store does not differ materially from that of any other retail store. The business is usually

too small to admit of the type of efficiency which can be secured only by having specialists charged with definite responsibility for certain divisions of the work. In most cases the manager himself is compelled to be a sort of business jack-of-all-trades. He is usually the responsible head of the store, and at the same time must act as buyer, head salesman, and bookkeeper. The man who combines efficiency in all of these kinds of work is rarely found, and is usually in business for himself. It is unusual for cooperative associations to be willing or able to pay the salary which will secure a man of this type. The salaries paid to the managers in the stores under consideration varied from \$45 to \$250 per month, making an average of \$106 a month for the 42 stores for which figures were obtained. This fact alone is sufficient to explain why the majority of the stores were not more successful than the tables indicate.

From the tabulated results of the questionnaire on page 4 it will be noted that only 7 stores report the employment of a man whose specialty is to act as sales manager, 4 report a special buyer, 10 a cashier, and 3 a stenographer. Thirty-one stores report the employment of a bookkeeper. Careful inquiry, however, leads to the conviction that all but a small proportion of these men are not capable of keeping a satisfactory set of accounting records. It is the almost unanimous verdict of the store managers that greater attention must be given to the office end of the business, and that the auditing must be more efficiently performed.

FINANCE.

The points covered in the section of finance bring out the essential differences between the corporate and cooperative type of organization. In general, it may be said that with the cooperative type the shares of stock are smaller; that these shares do not determine the voting power of the member; that paid-in capital stock usually bears a fixed rate of interest, while dividends are based upon the business and not upon holdings of stock; and that certain restrictions are placed upon stock transfer. The laws of most States require that a definite authorized capital be fixed in the charter or articles of association, while in others the amount of stock need not be fixed. The latter practice corresponds with the cooperative laws of several European countries and aims to permit an indefinite growth in the membership and capital stock.

For the 32 stores reporting the authorized capital, the average was \$45,437, while 41 stores giving the amount of capital subscribed average \$20,143, and 50 stores giving their paid-in capital average \$16,627. The shares of stock, as given in Table I, vary from \$1 to \$100, with an average par value of \$53. When questioned as to the

best size for a share of stock, most managers expressed themselves as in favor of the share of large denomination. It seemed to be the consensus of opinion that the share should not be smaller than \$25, but an examination of Table I indicates that much depends upon conditions. The character and density of population, the kind of business conducted, nearness to wholesalers, and many other features have a bearing on the best size for a share of stock. Well-capitalized stores were found with shares of small denomination, while other stores are very insufficiently capitalized on the basis of \$100 shares. In general it is considered inadvisable for any store in the United States to begin operations with a share of less than \$10, although here again there are exceptions.

TABLE I.—*The capitalization of typical stores.*

	Number reporting.	Total.	High.	Low.	Average.
Authorized.....	32	\$1,454,000	\$200,000	\$10,000	\$45,437
Subscribed.....	40	825,893	106,200	305	20,647
Paid up.....	50	831,377	106,200	267	16,627
Par value.....	44	.....	100	1	53
Paid up ¹	40	764,026	.....	.....	19,100

Vote: Forty stores allow 1 vote to each member; 5 stores allow 1 vote to each share of stock.

¹These are the 40 stores reporting subscribed capital, and are given separately for the sake of comparison.

Most of the stores allow members the privilege of paying for stock in installments. Others, again, sell their stock and receive some form of note or agreement to pay for it at a specified time. Both of these practices appear to have been greatly abused. The former accounts to a large degree for the discrepancy between the paid-up and subscribed capital as given in Table I, and the result of the latter has been that many associations have accepted poorly drawn notes which are not bankable, and which merely burden the books of the association with fictitious assets.

The following abstract from an auditor's report is illustrative of an abuse which has weakened many of the cooperative stores:

In view of the fact that a majority of your members have not liquidated their note obligation in payment for shares, I recommend that no patronage dividend be declared or paid covering the year 1914, and that the amount be carried as surplus. * * * Permit me, in conclusion, to express the hope that the members will pay their notes and thereby place the company where it rightfully belongs, and furnish the opportunity for it to grow large and successful.

A feature which probably has a greater influence on the successful capitalization of a store than the size of the share of stock is the amount of capital which one member may hold. Some of the earlier cooperative laws fixed the upper limit which one member could hold

at a figure which has since been recognized as too low. In the stores under discussion the upper limit varied from \$10 to \$8,000, with some stores placing no limit. It is difficult to say where the line should be drawn. With voting power restricted to 1 vote, with interest on capital stock limited to not more than current interest rates, and with the cooperative policy of distributing profits in proportion to the amount of business transacted by each member, it is difficult to see how serious injustice can result from the concentration of the bulk of the capital stock in the hands of a few members.

Of those stores reporting, 37 stated that interest was paid on the capital stock; the maximum given was 8 per cent, the minimum 5, and the average 7 per cent. These figures do not indicate any great advantage to the holders of capital stock. (See Table II.)

TABLE II.—*Practice as to the payment of interest and dividends on stock.*

Question.	Stores reporting yes.	Stores reporting no.	Average rate.	Remarks.
			<i>Per cent.</i>	
Interest on stock.....	37	8	7	3, 7 per cent; 2, 5 per cent; 12, 8 per cent; 11, 6 per cent.
Interest paid annually.....	34	.....	.....	
Interest paid semiannually.....	3	.....	.....	
Trade dividends paid to members.....	35	9	.....	
Trade dividends paid to nonmembers.....	18	25	.....	Usually half rate paid members.
Dividends paid annually.....	30	14	.....	2 pay by means of a monthly discount.
Dividends paid semiannually.....	3	39	.....	
Dividends usually paid in cash.....	27	9	.....	
Dividends usually paid in merchandise.....	7	29	.....	
Dividends usually paid in stock.....	3	35	.....	

The manifest purpose of the cooperative store is to make savings for its members in the purchase of household and other supplies. Patrons are charged the customary retail prices for the locality in which the store operates. Then, at the end of the specified period, the accumulated surplus is distributed in proportion to the purchases which each patron has made during the dividend period. Following the Rochdale plan, nonmembers are frequently allowed half the rate of dividends on purchases allowed members.

The figures given in answers to questions 51 and 57 of the questionnaire do not indicate the degree to which the cooperative stores are attaining their chief object—making savings for patrons. They indicate, rather, the provisions in the by-laws as to distribution of dividends and not the actual practice. While the information given was not satisfactory upon this point, it is believed that the vast majority of the cooperative stores have been a disappointment in the savings effected for members and patrons.¹

¹ See appendix, p. 30. Notes on the payment of trade dividends.

CREDIT.

Practically all of the stores required, at times, more capital than was provided by the sale of capital stock and accumulated surplus. The interest paid averaged 7 per cent, which can not be regarded as excessive (see Table III). As in the case of any other business, the ease with which a store is able to borrow depends upon its commercial rating. When a store is successful and has a high rating, it can secure all the capital it needs upon the note of the association. For many struggling stores, however, the only way in which credit could be obtained was by having those who were most interested indorse a bankable note in favor of the association. In many cases, especially where the borrowing has been done to bolster up a poorly managed and failing business, the practice of indorsing the notes of the association has been responsible for serious losses to members.

TABLE III.—*Practice as to credit.*

Question.	Number reporting.	Low.	High.	Average.	Yes.	No.
Do you borrow money.....					40	7
Rate of interest.....	37	6 p. ct.	10 p. ct.	7 p. ct.		
Is credit difficult to obtain.....					6	33
Security required.....					16	26
Are bills discounted regularly.....					18	15
Estimated annual discount.....	24	\$150	\$6,949	\$997		
Credit extended to customers.....					45	2
Losses due to credits.....	15	\$25	\$4,231	\$664		
Accounts paid promptly.....					25	5

It was found that some stores systematically used their credit at the bank in order to discount their bills, saving a profit to the store by this method. That this is not common, however, is indicated by the fact that only 18 stores reported the uniform practice of taking advantage of discount, while 15 never discounted their bills. Among those reporting the practice of discounting their bills, the saving ranged from a minimum of \$150 to a maximum of \$7,000 a year, with an average of \$1,673 for the 18 stores taking regular discounts. The figures indicate that not enough attention is given to this source of profit. It was found that among the most successful stores following the practice, the cash discount paid a considerable proportion of the operating expense. In addition to the saving effected, the practice of taking discounts has an important effect upon the wholesale houses and the buying efficiency of the store.

Of 50 stores, only 2 were found to be doing a strictly cash business. Most of the managers claimed that the extension of credit to customers was absolutely necessary. The time for which credit was allowed varied from 1 to 6 months, the average credit period given for 27 stores being 2 months.

The practice is unfair in that the man who pays cash usually secures goods at practically the same price as the man who uses 6 months' credit. This unfairness has led to the practice among a few of the most successful stores of charging interest on all bills running over 30 days. In many cases it was found that inexperienced managers, in their enthusiasm to expand the business, had involved the association in serious difficulty by a too wide and promiscuous granting of credit to customers. In some instances it was found that the accounts receivable amounted to more than the entire subscribed capital stock.

On the other hand, one of the advantages claimed for the cooperative farmers' store is that it serves as a credit institution, tiding the members over until harvest or until "pay day." Indeed, one of the most successful stores preferred to do a credit business, and reported that 98 per cent of its trade was on this basis. The reasons given for its preference were greater simplicity and uniformity in its accounting system and the larger volume of trade resulting from the credit business. The reports of 36 stores showed that, on the average, half of the sales were on credit and the other half cash.

For 24 stores the average annual loss due to the granting of credit is 1.17 per cent. This is much higher than the average for stores under private management, as indicated by the results of the Harvard survey, which found the common loss for bad debts to be one-half of 1 per cent.¹ Moreover, there is reason to believe that this does not tell the whole story. As a matter of fact, the estimate placed by the manager of an unsuccessful cooperative store upon the uncollectible proportion of the accounts and bills receivable, which he is carrying upon his books, is very unreliable. In one case, which is probably typical of many others, the amount was estimated at \$145 for the year, when, in reality, the amount which was afterwards found to be uncollectible was nearer \$2,000. This loss, of course, falls upon all who pay for their goods.

Entirely apart from the loss involved, the credit system is unjust. Either those enjoying credit should pay interest, or customers paying cash should receive a cash discount. The reports of those who have tried to do business on a cash basis indicate that the credit system has become so rooted in American business as to be practically ineradicable. Many of those questioned characterized it as "a necessary evil."

PURCHASING.

Table IV, showing the practice regarding purchasing, is largely self-explanatory. One important fact, however, is not brought out

¹ Harvard University. Bureau of Business Research. Bul. 5: Expenses in Operating Retail Grocery Stores. 1915. Sup. 7.

by the table—a fact which many merchants overlook. The most successful stores confine their purchases to a few reliable firms, rather than scatter their orders among too many wholesale houses. In fact, one store on the verge of bankruptcy ascribed its failure in large part to this practice, since, in time of difficulty, it could claim but little support from its numerous creditors. Among the many objections to scattered buying are: (1) Greatly increased and useless office work; (2) divided support of the wholesalers; (3) excessive buying and danger of overexpansion; (4) too great diversity of stock; and (5) loss of advertising opportunity afforded by standard lines.

TABLE IV.—*Practice in purchasing.*

Question.	No. re- porting.	Low.	High.	Aver- age.	Yes.	No.
Largely from salesman.....					43	.....
From catalogue houses.....					19	21
From manufacturers.....					24	19
Are lowest prices obtained.....					27	11
Produce from farmers.....	22	\$1,500	\$35,000	\$12,126	.....	.....
All orders reduced to writing.....					10	30
Invoices checked systematically.....					39	2

It is interesting to note that only 27 stores believed that they bought at the lowest price, while 11 said positively that they bought at a disadvantage. The reasons given were: (1) Inability to take advantage of discounts, and (2) in a few cases, discrimination on the part of wholesale houses against the cooperative store. The former handicap is to be traced generally to such causes as insufficient original capital, tying up of capital in accounts receivable, overinvestment in slow-moving or dead stock, loss of capital through bad management, etc. On the latter point a few stores asserted that they were sometimes discriminated against in the prices they were compelled to pay; that they were not given equal credit privileges with private and corporate enterprises; and that they were refused certain lines of goods at any price. Credit men say that this obtains only when the store has unsatisfactory credit rating or record and when cut prices and discounts are allowed on fixed-price goods.

SELLING.

As shown in Tables V and X, the annual sales of the stores under consideration ranged from \$7,500 to \$623,703, with an average approximating \$88,000. Table X includes only 35 out of the 60 stores visited during the survey, and it will be noticed that of these 5 were unable to give sufficiently complete data for a statistical estimate of their financial success.

TABLE V.—*Practice as to selling.*

Question.	Stores reporting.	Low.	High.	Average.
Per cent country trade.....	43	0	95	63
Per cent town trade.....	43	5	100	37
Per cent membership trade.....	42	10	98½	60
Per cent nonmembership trade.....	42	1½	90	40
Per cent active members.....	37	25	100	80
Per cent nonactive members.....	37	0	75	20
Per cent cash sales.....	36	2	85	50
Per cent credit sales.....	36	15	98	50
Total sales.....	45	\$7,500	\$623,703	\$87,781
Rate of profit on sales ¹	36	12 p. ct.	30 p. ct.	20 p. ct.

¹ This is the estimate made by managers (see Table X).

The percentage of expense to sales indicates a wide variation, ranging from 7 to 17 per cent. Even more surprising is the range in the percentage of gross profit made on the business, ranging from 10.5 per cent to 24.5 per cent. In accounting for this range one element is the kind of business. The higher figures are for businesses having a large trade in dry goods, shoes, and men's furnishings, while the lower rates were made in stores handling groceries and a few farm staples. The percentage of net profits to sales shows the variation one would expect.

Almost all of the stores under survey were located in country towns, with the majority of the membership drawn from the farms. Hence there is an average of 63 per cent of farmers' patronage for the 43 stores reporting, with a range of from 4 per cent to 95 per cent of country trade.

Most of the stores reported a large percentage of nonmembership trade, the range being from 1½ per cent to 90 per cent, with an average for the 42 stores reporting of 40 per cent of the trade from nonmembers.

This nonmembership patronage is due to several factors. Eighteen of the stores hold out the prospect of some dividends on purchases to nonmembers, thus securing trade. Again, many persons are in sympathy with the cooperative movement and expect to become members if the store succeeds, and in the meanwhile they give it a share of their trade. Finally, a great deal of the nonmembership trade which falls to cooperative stores is more or less accidental and due to the fact that many Americans give little thought to their choice of a place to trade. This indifference also helps to some extent to account for the fact that 34 stores reported an average of 20 per cent of their members as "nonactive," showing little interest in the store and giving it practically none of their trade.

It was found that success, loyalty of members, and nonmembership trade hang very closely together. Let a store fall behind and fail to pay dividends and it soon loses the support of both members

and nonmembers. The opposite case is illustrated by the experience of one of the most successful stores, which in 26 years has missed paying a dividend but once. It reported 100 per cent active members and a large nonmembership trade.

It must be admitted that in general the results in net profits are somewhat discouraging. Only 11 stores out of 60, or 18½ per cent, were able to show a net profit of 5 per cent or over.

If we conclude, as we are forced to do, by the supplementary notes found in the questionnaires, that the 30 stores for which the net profits could not be calculated would make a still poorer showing, we are convinced that much greater caution should be exercised before starting cooperative stores.

ACCOUNTING, REPORTS, AND AUDITING.

One of the principal objects of this survey was to ascertain the business practice of existing cooperative stores and to study their systems of accounting and auditing. Questions 93 to 150 in the questionnaire show the different points which were studied with great care. In addition to recording the answers to these questions, the investigator aimed to see as much of the accounting and office system as time and conditions would permit. As has been stated, the survey made evident that the business practice, including the system of records, is probably the weakest point in the management of cooperative stores. Investigations by the Office of Markets and Rural Organization have shown this to be true of nearly all other cooperative enterprises.¹

This weakness is due to lack of training on the part of the managers themselves, to inability to pay the salary required by trained accountants, and to the general failure on the part of the membership of cooperative associations to realize the importance of a clear and constant record of the state of their business.

To the question, "Is the accounting system satisfactory?" 20 managers answered in the affirmative, 16 answered "Fair," 9 answered in the negative. The investigator's "remarks" show that the closer examination which he made of the systems led him to believe that a very small proportion of the stores visited had what could reasonably be called a satisfactory system of accounting. In fact, in almost 50 per cent of the cases, the results of the attempts to get answers to questions relating to the status of the business showed that the managers themselves had no definite records from which they were able to give a satisfactory statement of the condition of the business.

¹ Bassett, C. E., Moomaw, Clarence W., and Kerr, W. H., Cooperative Marketing, and Financing of Marketing Associations. In U. S. Dept. of Agriculture Yearbook 1914, pp. 185-210. Kerr, W. H., and Nabstoll, G. A., Cooperative Organization Business Methods, U. S. Dept. of Agr. Bulletin 178, 1915, p. 20.

TABLE VI.—*Showing business practice, accounting, and auditing.*

Question.	Yes.	No.	Month-ly.	Quar-terly.	Semian-nually.	Annu-ally.	Remarks.
Satisfactory system.....	20	9					15 fair.
Double entry.....	36	5					
Total cash deposited daily.....	9	28					
Sales slips used.....	42	3					
Cash coupons used.....	12	27					
Billing ledger used.....	10	32					
Cost accounts kept by depart-ments.....	10	34					
Manager reports regularly.....	40	9	20	1	18	9	8 report both monthly and annually. 3 weekly; 3 bimonthly.
Are audits made regularly.....	34	8	11	2	3	10	
By committee of members.....	21	22					
By professional auditor.....	17	26					High, \$300; low, \$30; average, \$56.
Are members competent.....	8	27					
Cost per year.....							
Cash register used.....	39	6					
Customers account file.....	20	23					
Typewriter.....	25	19					
Adding machine.....	24	20					
Satisfactory filing equipment.....	29	15					
Overhead carrier.....	10	34					
Check protector.....	17	26					

One thing that impressed the investigator was the lack of uniformity of systems, forms, and equipment. This lack made it very difficult to secure statistics which would give a comparative estimate of the success of the stores. The investigation conducted by Harvard University in its attempt to bring about standardization of accounts and office methods disclosed the same lack in practically all other retail stores.

Among cooperative stores, a beginning in the right direction has been made by two or three promoters who are attempting to install uniform systems of accounting and auditing for the stores they organize. An examination of the work of these promoters, however, tends to show that the good they are accomplishing is largely offset by the fact that they have started many stores for which there was not sufficient demand in the locality, and which were therefore doomed to failure from the start. Moreover, they have frequently advised an association to purchase an old, and sometimes failing business, and in many of these instances the cooperative association found itself in possession of a large stock of shopworn goods and a tradition for inefficiency in the store which was hard to live down, although it had been paid for as "good will."

No less than 36 of the stores reported that their books were kept by double entry; but where it was possible to get at the facts, it was found that the systems were very imperfect, and that in many cases it would have been difficult to secure a trial balance from the records. It is probable, however, that the fundamental weakness is in the bookkeepers rather than in the systems of accounting. This is shown in a number of instances where systems of accounting, installed by experts, have become entirely disorganized through the inefficiency

of the bookkeepers. On the other hand, one of the most successful stores studied in the survey had an accounting system which was crude and out of date. Although the system was kept in a set of old-style books, which necessitated a great waste of energy, the work was done so thoroughly that the records were up to date at all times, and at a moment's notice the management could find out the exact state of the business.

One good feature in the systems of records is the almost universal use of the duplicating or triplicating sales slips. In those cases where the triplicating sales slip was used systematically, and the triplicates carefully checked at the close of each day, the office system was found to be securing fairly accurate results.

The cash coupon seems to have gone out of favor; only 12 reported using it and 27 answered in the negative. Among the 12, several forms were found. The most common was the book form with coupons of different denominations perforated for ready detachment. Another type resembled the mileage book commonly used on railroads, with cents represented instead of miles. Various forms of tickets and metal checks were used in paying for produce. Like the coupons, these were redeemable in goods.

The billing ledger was reported as being used in 10 stores, while 32 answered in the negative. When it is not used, amounts of sales are either posted from the sales slips to an ordinary ledger, from which statements are rendered at the end of each month, or the sales slips are filed in the short-account filing cabinet as customers' ledger accounts.

Ten stores reported that they were keeping cost accounts by departments, while 34 reported in the negative. Further examination, however, showed clearly that not over 1 or 2 stores out of the 60 actually kept accounts by departments in such a way as to show the cost of operation and profits for each department of the business. Closer questioning revealed the fact that the stores recognized the advantage of having departmental accounts, and intended to organize their bookkeeping system on that plan; but for various reasons, usually because of the lack of a sufficiently trained bookkeeper, they had not yet put their plans into operation.

The by-laws of practically all of the stores examined require that the manager shall make reports at stated intervals. This provision seems to be adhered to with more or less regularity. Twenty of the stores required the manager to report monthly, 18 semiannually, 9 annually, 1 quarterly, and 1 daily. Eight of those requiring an annual report were included among those requiring a monthly report.

Defective as are the bookkeeping systems of cooperative stores, their auditing is still more unsatisfactory, although 32 reported that

a regular audit is made. Of these, 13 required that the audit be made weekly, 11 monthly, 3 bimonthly, 2 quarterly, 3 semiannually, and 10 annually. In addition to these, several others stated that they had an audit at more or less irregular intervals. When questioned as to the auditors, 21 stated that the auditing was done by a committee elected from the membership, while 17 reported that the services of a professional auditor were secured. When further questioned as to the cost per year of the auditing, only 15 stores reported a regular outlay for this purpose. Of these, the highest gave an annual cost of \$300, while the lowest was \$30, the average for the 15 stores being \$56 each.

The results of this survey demonstrate that the precariousness of the cooperative mercantile business is due to inefficient accounting and auditing more than to any other single cause. Where complete records are kept of the business, and where these are used as the basis of a regular monthly financial report, there is furnished a continuous barometer by which a board of directors can take warning at the first signs of mismanagement or failing business. In addition to this, at the end of each fiscal year some competent outsider, preferably a certified public accountant, should be hired to audit the records for the year.

Of course it must be recognized that efficient bookkeeping and expert auditing cost more than the small cooperative business can afford. Much progress toward efficiency, however, may be secured by the adoption of some simple standardized system of bookkeeping and business practice that will give complete and accurate records which can be easily interpreted. To meet this need the United States Department of Agriculture has devised a system which is described in Department Bulletin No. 381, entitled "Business Practice and Accounts for Cooperative Stores."

The auditing committee elected by the members should not undertake to do the annual auditing itself, unless it enjoys the rare advantage of having a certified public accountant in its membership. The members of the committee should know enough of bookkeeping to appreciate the necessity of accuracy. They should see to it that this is accomplished, and the association should make provision for the necessary expense.

These conclusions have been borne out by the long experience of the Rochdale stores in England. Their experience is summarized in the preface to "A Manual of Auditing," published by the Cooperative Union (Ltd.), with headquarters at Manchester, England, for the guidance of the societies. The author says:

It is essential to the interest of members of societies generally that great attention be paid to the importance of strict audit, first, for self-protection;

second, in the interest of the societies generally; third, for the protection of the creditors with whom the society may do business; fourth, for the maintenance of the reputation of the cooperative movement. The true end and aim of every system of audit being supervision, external check, and testimony, experience proves the necessity of the officers of cooperative societies understanding the principles of bookkeeping, followed up by an efficient and strict audit of accounts. With this end in view, we propose to lay down a treatise, arranged in systematic order, placing fully before those who may consult these pages a safe mode for auditing the transactions of societies.

EQUIPMENT.

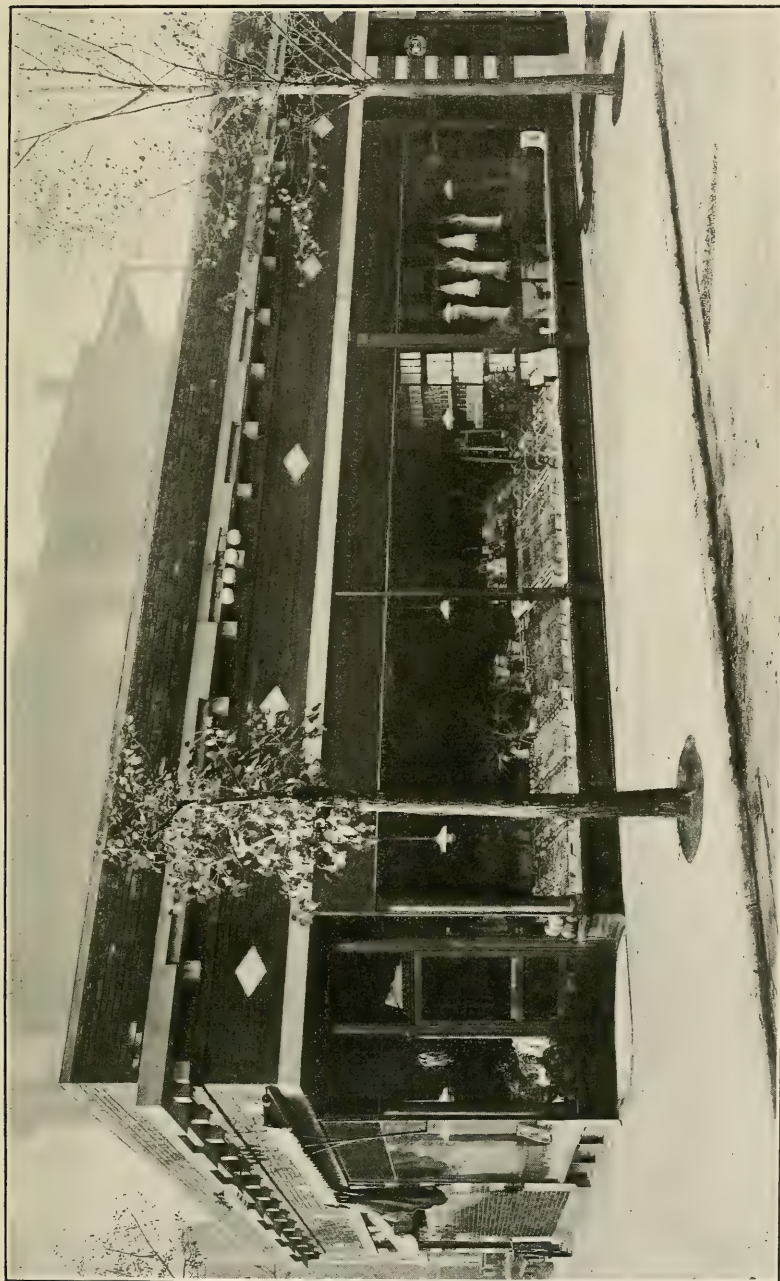
The answers to the questions on mechanical equipment which are summarized in Table VI are self-explanatory. They indicate that the average cooperative store is about as well equipped as the average store under private or corporate management. There was a wide variation in the stores studied, however. The equipment ranged from small, poorly lighted, and insanitary stores, without cash registers, filing equipment, or any other mechanical convenience, to one or two of the most modern stores to be found in the United States (see Pl. I).

It was found that most of the managers appreciate the economy of many of the devices entering into modern store equipment, and their absence in a store is usually due to a lack of funds. There is also a general demand among patrons of all classes for a store that is up to date in its equipment and appearance. (See Pl. II.) To some extent this demand would seem to be part and parcel of the modern efficiency movement, which is reaching a considerable proportion of farm homes in the form of modern household conveniences and farm appliances.

THE BALANCE SHEET.

Table VIII and Sections XIII and XIV of the questionnaire present a summary of the resources and liabilities for 46 stores. The most interesting figures are those showing the surplus, undivided profits, and unpaid dividends, amounting to a total of close to \$460,000, or an average of almost \$10,000 per store. From these figures it would appear that the stores are in a very prosperous condition. Only 4 stores out of 46 show a deficit aggregating \$9,214. Moreover, if to the amount of average surplus, undivided profits, and unpaid dividends, the capital stock of \$15,948 is added, the total average resources will exceed the average liabilities by \$25,676.

If the stores are in such splendid financial condition, why is it that most of them are not paying regular dividends? The fact is that for the majority of the stores this prosperity is more apparent than real. In the first place, the stock carried is too large and the average number of stock turns a year too low. Many of the stores are carrying a lot of stock which is dead for the greater part of the



EXTERIOR VIEW OF A MODERN COOPERATIVE GROCERY AND MARKET.



INTERIOR VIEW OF A MODERN COOPERATIVE GROCERY AND MARKET.

year, and are listing at full value goods which are shopworn and upon which it will never be possible to realize in full. Then, too, the accounts receivable, bills receivable, and miscellaneous assets, with a total of over \$700,000, an average of \$15,000 per store, contain many items which can never be collected and should be dropped, as they only becloud the financial condition of the store. As an illustration, one small store has been carrying \$1,200 worth of notes taken for shares of stock, although they are all past due; and the same association has on its books over \$2,000 in accounts which might almost as well be wiped out and charged off to loss and gain. This large proportion of more or less fixed and doubtful assets probably goes far toward explaining the reason why dividends can not be paid.

TABLE VII.—*The balance sheet.*

[46 stores.]

	Total.	High. ¹	Low. ¹	Average.
Resources:				
Cash.....	\$95,439.97	\$20,997.40	\$28.15	\$2,074.78
Merchandise.....	830,272.96	98,460.12	800.00	18,049.41
Equipment.....	75,449.40	10,195.88	23.00	1,640.21
Accounts receivable.....	339,758.05	48,549.71	-----	7,386.05
Notes receivable.....	95,255.10	12,253.77	-----	2,070.76
Miscellaneous.....	259,583.69	28,502.83	-----	5,643.12
Total.....	1,695,759.17	201,091.24	1,113.00	36,864.33
Liabilities:				
Capital stock.....	733,592.74	106,200.00	267.00	15,947.67
Bills payable.....	236,986.04	22,000.00	-----	5,151.87
Accounts payable.....	232,579.93	18,363.84	-----	5,056.00
Surplus.....	200,242.68	33,318.14	6.02	4,353.10
Undivided profits.....	238,406.18	13,750.60	5.57	5,132.74
Unpaid dividends.....	8,844.96	3,343.92	-----	192.28
Miscellaneous.....	45,106.64	19,200.00	30.00	980.58
Total.....	1,695,759.17	201,091.24	1,113.00	36,864.33
Total resources.....	1,695,759.17	-----	-----	36,864.33
Total liabilities, exclusive of capital stock, surplus, undivided profits, and unpaid dividends.....	514,672.61	-----	-----	11,188.54
Total net worth.....	1,181,086.56	-----	-----	25,675.79

¹ Figures in these columns are independent of each other, and the totals represent high and low totals not totals of the other figures given.

OPERATING EXPENSES.

Table VIII shows the annual operating expenses of 41 stores. This table shows salaries and labor, which appear separately in Table IX. The comparative statement of expenses in relation to net sales is found in Table X, which should be studied carefully in this connection. The number of stores reporting each of the various items in Table VIII indicates how difficult it was to get satisfactory figures under the different subheads in the questionnaire. In fact, it was found to be impossible to make a segregation of the expenses on account of the difference in classification used by the stores. Many

of them did not segregate their expense accounts at all, but included everything under the one title of "General expense."

TABLE VIII.—*Annual operating expense.*

	Number of stores.	Total.	High.	Low.	Average.
Salary and labor.....	31	\$145,553.98	\$12,021.95	\$720.00	\$4,695.93
Rent.....	23	20,279.76	1,800.00	84.00	881.51
Light and heat.....	16	2,194.18	250.00	24.00	137.14
Insurance.....	30	9,054.41	1,905.44	22.00	301.81
Taxes.....	21	5,957.55	1,259.22	25.00	283.69
Telephone and telegraph.....	8	347.50	56.00	25.00	43.44
Interest.....	25	14,695.68	2,300.00	37.00	587.83
Postage and stationery.....	5	874.44	644.32	25.00	174.89
Miscellaneous.....	36	195,022.36	83,623.79	7.10	5,417.29
Total expense ¹	41	393,979.86	86,553.74	946.00	9,609.27
Profit for year.....	31	178,229.31	.....	.....	5,749.33
Loss for year.....	2	2,453.38	.....	.....	1,226.09

¹ The different columns will not balance since the answers are given in each case for the number of stores indicated.

TABLE IX.—*Monthly salaries and labor.*

Question.	Number of stores.	High.	Low.	Average.
Manager.....	42	\$250.00	\$45.00	\$106.00
Bookkeeper.....	27	125.00	10.00	68.87
Head salesman.....	31	150.00	45.00	74.13
Other salesmen.....	31	90.00	55.00	49.95
Saleswomen.....	26	55.00	16.00	32.10

Officers and directors usually receive the nominal sum of \$1.50 per meeting, except where they are actively engaged in the business, when they are paid a salary for managerial or accounting services.

It is believed that the salary and rent items for 32 and 23 stores, respectively, are fairly trustworthy, the average salary roll being about \$400, and the average rental about \$75 per month. Even these items are not typical of the stores covered by the survey, on account of the small proportion included.

The percentage of expense to net sales is not excessively high. It ranges from 7 to 17, with an average of 11.7. This percentage is for 33 of the stores, and is probably a much better showing than would have been made had all the stores been able to contribute to the data from which this percentage was calculated. In view of the fact that some of the managers stated it as their belief that it cost somewhat more to run a cooperative than a privately owned business, this percentage is surprisingly low. The Harvard investigation of grocery stores found the lowest cost of operation to be 10.4 per cent of sales, the highest 25.2 per cent, and the common percentage 16.5, as against the cooperative averages just quoted.

In considering this showing for the expense of operation, there must be taken into account the average gross profit of 21 per cent for

the stores studied by Harvard as against 17.7 per cent for the 30 cooperative stores for which the gross profit could be calculated. The circumstances under which this investigation was made did not permit the investigator to go back of the accounting system in every case to see whether the data upon which gross profits could be estimated were sufficiently reliable.

For some of the stores not included in this percentage column of gross profit, it was quite certain that the manager was working in the dark, and did not actually know the amount of his gross profit. For example, in several cases a manager who handled principally groceries and farm produce said that his gross profit was about 21 per cent. Upon analyzing the statements, however, the amount was found to be very much below what he estimated. This was due to the fact that certain commodities, such as butter, eggs, sugar, flour, and practically all farm produce was handled upon a very close margin, and sometimes at an actual loss. These items bulked much more largely in the total business than the manager realized. One store, for example, went bankrupt within a period of 10 months because its manager thought he was running upon an average of 20 per cent gross profit, while in reality he was running at a net loss of 7 per cent on sales, and his gross profit was only a little over 10 per cent.

Referring once more to Table X, we find that the average cost of all salaries and labor amounted to a total of 6.4 per cent of the net sales as compared with 11.7 per cent for the total expense. That is, the salaries and labor form 54.7 per cent of the total expense of running the business. This surely is not excessive. The Harvard survey of grocery stores disclosed the fact that the salaries in the average retail grocery under private management were 60.6 per cent of the total expense, or almost 6 per cent higher. This is borne out by Table IX, which summarizes the results of the investigation of wages paid. For 42 stores the average salary paid the manager was \$106 per month. But if 6 of the stores which pay their manager \$150 per month or over are eliminated, the average for the other 36 amounts to only \$79.50. The average salary for the bookkeeper was also too low to secure efficiency. The 10 States in which these stores are located have average wages considerably higher than the average would be for the country as a whole; from this it is seen that the wages paid by the cooperative stores are very low.

In addition to the regular salaries and wages indicated in Table X there are insignificant outlays for officers and directors, and often for an occasional helper. The most common policy is for associations to pay their directors \$1.50 for each meeting attended, except where they occupy a position in the business on regular salary. Occasional help costs the daily wage of from \$1 to \$2.50 a day, with an average

of about \$2 per day. The proportion which these items bear to the total wages paid is not very significant and has been included in the labor percentage column in Table X.

In addition to their regular wages, the cooperative laws of some States stipulate that employees shall receive dividends on the amount they receive as wages, just as members receive dividends on purchases. As a matter of fact, however, this principle of dividends and bonuses to employees is generally ignored, and some stores even go so far as to stipulate in their by-laws that no employee shall receive any reduction on purchases. Employees in such stores must become members in order to participate in dividends. Among the stores visited during the survey only 2 were found which actually had distributed dividends on wages.

TABLE X.—*Important percentages based on sales.*

Store No.	Sales.	Ex- pense.	Per cent.	Salary and labor.	Per cent.	Net profit.	Per cent.	Per cent gross profit.	Inven- tory.	Stock turns per year.
1.....	\$623,703	\$86,554	13.8			\$66,282	10.6	24.4	\$98,460	6.3
2.....	232,000	10,221	7.0	\$11,261	5.0	10,050	4.3	11.3	30,477	7.3
3.....	200,000	24,915	12.4			6,375	3.1	15.5	51,952	3.8
4.....	177,546	24,904	14.9			8,712	4.9	18.9	67,588	2.5
5.....	174,997	23,037	13.1	12,022	7.0	4,377	2.5	15.6	24,104	7.3
6.....	168,546	16,115	9.6	10,193	5.5	17,192	10.2	19.6	42,660	3.8
7.....	143,000	11,522	8.0	9,000	6.3	9,927	6.9	14.9	40,007	3.5
8.....	129,395	14,941	11.5	7,801	6.0	9,313	7.2	18.7	30,781	4.2
9.....	96,000	12,558	13.0	6,472	6.8	5,170	5.4	18.4	11,169	8.6
10.....	95,916	13,325	13.9	6,440	6.7					
11.....	87,009	7,285	8.3			9,763	11.2	18.4	9,924	8.8
12.....	69,000	6,840	9.9	4,980	7.2	648	.9	10.8	31,071	2.2
13.....	68,000	10,114	14.9	6,075	9.0	1,753	1.1	13.8	11,850	5.7
14.....	67,074	8,164	12.2	4,909	7.3	2,686	4.0	16.2	19,075	3.5
15.....	65,768	6,445	9.7			4,424	6.7	14.9	4,066	16.1
16.....	65,152	6,719	10.2	3,982	6.1	3,775	5.8	16.0	18,413	3.5
17.....	63,978	6,938	10.8	4,359	6.9	1,453	2.2	13.0	19,141	3.3
18.....	60,000	5,404	9.0	2,685	4.5	928	1.5	10.5	14,563	4.1
19.....	60,000	5,037	8.3	3,800	6.3	2,774	4.6	12.9	18,161	3.3
20.....	56,000	5,512	9.8	3,563	6.4	4,032	7.2	17.0	16,122	3.4
21.....	44,000	5,332	12.1	2,858	6.3	3,279	7.4	19.5	15,587	2.8
22.....	44,000	4,964	11.3	3,080	7.0	536	1.2	12.5	8,799	5.0
23.....	42,000	6,097	14.5	3,960	9.4	1,310	3.1	17.6	18,278	2.3
24.....	41,000	4,167	10.1	3,015	7.4	1,245	3.0	13.1	11,004	3.7
25.....	40,000	4,620	11.5	3,300	8.2	783	2.0	13.5	7,249	5.5
26.....	40,000	5,169	12.9	3,246	8.0	400	1.0	13.9	9,300	4.3
27.....	40,000	4,000	10.0			1,701	4.2	14.2	9,158	4.3
28.....	38,000	5,949	15.5	3,357	8.8				12,816	2.9
29.....	36,413			2,752	7.7				9,171	3.9
30.....	34,804	3,086	8.8	1,772	5.2	1,027	3.0	11.8	7,495	4.7
31.....	22,000	3,730	17.0	1,900	8.6	460	2.1	19.1	6,733	3.3
32.....	20,000								8,341	2.4
33.....	20,000	3,249	16.2	1,976	9.8	138	0.7	16.9	8,813	2.3
34.....	19,000	2,957	15.5	1,620	8.5				8,999	2.1
35.....	7,500	946	12.6	720	9.5	362	4.8	17.4	1,731	4.4
Average.			11.7		6.4		6.0	17.7		4.4

¹ Loss.

The directors of one of the most progressive of the stores have made the provision that when profits reach a certain figure employees are made participants in the increase. This is in the form of a bonus, the payment and amount of which is left to the discretion of the board of directors.

As has already been noted in the introductory section, the results summarized in Table X can not be considered conclusive. In the first place, the number of stores having accurate records is too small. Again, the great variety of method in keeping the records makes it impossible to classify the data accurately. Finally, although most of the 30 stores from which the best records were obtained are of the general-merchandise type, the number of departments and the amount of business done in each varies greatly throughout the list. The rate of profit as well as the expense of handling varies for each kind of goods, such as groceries and provisions, dry goods, boots and shoes, drugs, hardware, and implements. Accurate comparison of operating expenses would necessitate separate sets of records for each of these different lines, but since expenses are not segregated, it follows that a comparison of operating expenses does not give an accurate index of the efficiency of the management.

However, the table does indicate that it is possible to make a saving through cooperative stores. It indicates also, to some extent, the conditions under which a saving is possible. There are two factors entering into the determination of the net profit. The first is the percentage of gross profit made on sales and the second is the percentage which the expense bears to sales. The table indicates the relationship which must exist between these percentages if a saving is to be made which will justify the existence of a cooperative store. The careful manager should never delude himself by vague generalities, but must take into account every single factor in his business bearing on both the gross profit and the expense. Only by constant checking on both of these factors can he be certain of permanent success.

TABLE XI.—*Summary of preceding tables.*

Average number of members (43 stores)	228
Total resources (46 stores)	\$1, 695, 759. 17
Total liabilities (46 stores)	\$514, 672. 61
Total paid-up capital (50 stores)	\$831, 377. 98
Average resources (46 stores)	\$36, 854. 33
Average liabilities (46 stores)	\$11, 188. 54
Average paid-up capital (50 stores)	\$16, 627. 56
Average net worth (46 stores)	\$25, 675. 79
Average surplus, undivided profits, and unpaid dividends (46 stores)	\$9, 728. 12
Average per cent membership trade (42 stores) per cent..	60
Average per cent credit sales (36 stores) do	50
Average rate of interest paid on borrowed capital (37 stores) per cent	7
Average per cent active members (37 stores) per cent..	80
Average annual sales (45 stores)	\$87, 781. 91
Average gross profit on sales (29 stores) per cent..	17. 7

Average rate of operating expenses on sales (33 stores) _per cent_	11. 7
Average produce bought (estimated) (22 stores) _	\$12, 126. 08
Average annual cost of audit (15 stores) _	\$56. 00
Manager's average monthly salary (42 stores) _	\$106. 00
Salesmen's average monthly salary (31 stores) _	\$50. 00
Saleswomen's average monthly salary (26 stores) _	\$32. 00

OBSERVATIONS AND CONCLUSIONS.

The figures collected in this survey bring the conclusion that the majority of the cooperative stores established are unsuccessful in achieving their main object—saving on purchases to members and a reduction of the high cost of living. This conclusion is borne out by the supplementary notes collected from managers who could not apply statistics, and by notes on interviews with leaders who are acquainted with the store movement in whole sections which could not be covered in detail. But that there is one real service which the cooperative stores have performed seems to have been demonstrated again and again. Even in cases where stores have failed absolutely and gone into bankruptcy, they have frequently been responsible for the introduction of improved business methods in the towns where they were established. They have had the effect of stimulating competition. In cases where the merchants have competed keenly against the cooperative store, they have been compelled to adopt more efficient business methods. This has resulted in lower prices to every consumer in the locality and frequently in better prices to farmers on produce.

In the case of one particular farmers' store, it was estimated that the farmers of the locality received an increase on their butter, eggs, and poultry in one year which would have amounted to more than the entire paid-in capital stock of the cooperative store. This gain went to every farmer in the community regardless of whether or not he was a member of the cooperative association.

TABLE XII.—*General comments.*

Is the business in satisfactory condition (manager's opinion) _	32 yes; 15 fair; 1 no.
Has the business been reorganized _	6 yes; 37 no.
Expansion planned _	12 yes; 30 no.
Educational propaganda _	12 yes; 30 no.
Probable future (manager's opinion) _	Bright, 20; good, 11; fair, 3; doubtful, 12; not good, 3.
Cooperation with other merchants _	8 yes; 33 no.
Are employees members? _	9 yes; 24 no.
How do expenses compare with private business in town? _	4 higher; 12 same; 11 lower.

The manager of one of the most successful of the stores included in the survey expressed the conviction that the cooperative store is to the business community what the governors are to the steam engine, and that on account of its regulative influence there ought to be a cooperative store in every town. The same manager was of the opinion that it would be an equally undesirable condition to eliminate privately owned business from any town.

In addition to whatever salutary influence the cooperative store may have upon the business community, the survey shows that there are possibilities in the cooperative store, if properly organized and managed, for the accomplishment of important savings to members, thus opening the way for a reduction of the high cost of living. This leads to a summary of the conditions of success and the causes of failure.

Briefly stated, the conditions of success may be summarized under the headings¹: (1) Leadership; (2) capable management; (3) favorable environment; (4) adequate legal safeguards.

(1) *Leadership*.—In every case where a store was found to be a conspicuous success, that success could be traced to the influence of some conspicuous leader. The part which leadership plays in holding the membership of the association loyal to their store is not confined to the organizer. The outstanding leader who has the ability to round up the community must be supported by others who have some talent for leadership. The manager himself must be “a good mixer.” In fact, in the most successful stores every clerk has been chosen with a view to adding more enthusiasm and support to the business. Leadership, to be permanently successful, must build up an organization which will be self-supporting and self-perpetuating. A mistake frequently made by the leader responsible for the establishment of a successful association is that he does not provide the necessary organization which will enable it to perpetuate itself after he has severed his connection. Where such is the case, the society is foredoomed to go to pieces as soon as the strong leader is removed. Cohesion must ultimately rest on education, on loyalty to an institution, and on principle rather than on the blind following of a leader.

(2) *Capable management*.—After all that has been said, little need be added in support of capable management as an essential condition for the success of the cooperative store. It should always be remembered that business efficiency is as essential in the cooperative as in any other type of business organization. Unfortunately for the movement, the average enthusiast who feels a call to promote the cooperative movement has in the past laid more stress on sentiment

¹ Compare with the rules adopted by the Rochdale pioneers in 1844 and the causes of failure of cooperative stores as given in: Wisconsin State Board of Public Affairs. Report upon Cooperation and Marketing, 1912, pp. 29, 34.

than on business efficiency. This type of promotion is usually followed by a policy which soon brings the business to a disastrous end.

(3) *Favorable environment.*—In several communities in which successful cooperative stores were found, investigation revealed that there had previously existed some natural bond of union, which in itself was an important factor in determining the welfare of the business. Of these may be mentioned predominating nationality, common occupation, church affiliation, and fraternal organization. The existence of such communities may be taken as a good omen for the success of any kind of business organization on the cooperative plan.

(4) *Adequate legal safeguards.*—A cooperative association, even more than a corporation, requires a legal standing which will secure safety. Every cooperative association is intended to be a sort of public-service institution, and, as such, it should have the legal safeguards which some States have provided by recently passed cooperative laws. In one of these laws, a survey of the locality is strongly recommended before an organization is effected. The same law requires financial statements to be sent twice a year to an official charged with the duty of protecting members of cooperative associations.

The causes of failure, it is evident, are largely the opposite of those conditions which make for success. The converse of the foregoing four conditions of success would be: (1) Lack of leadership; (2) poor management; (3) unfavorable environment; and (4) lack of proper legal safeguards.

(1) *Lack of leadership.*—Frequently an outside leader comes into the community and through his enthusiasm arouses the people to a condition in which they are ready to enter upon the establishment of a cooperative store. Then, after seeing the enterprise started, he goes to other communities and leaves the association to work out its own salvation. In many such communities the organization dies from lack of interest as soon as the promoting spirit is gone. In other cases, the leadership in a community may be of such an unpractical character as to lead the association into attempting something which is actually impossible of realization. In such cases, also, disaster is sure to follow.

(2) *Poor management.*—Let the management be ever so efficient, an association may still fall short of success if unpractical leaders force it into attempting the impossible. But even if it be presupposed that the business is adapted to the needs of the community, and every other condition favorable, it may still fail entirely through bad management. Among the outstanding shortcomings of the inefficient manager have been noticed reckless buying, excessive exten-

sion of credit, too great overhead expense, overexpansion, failure to provide a surplus, no allowance for depreciation, inefficient business practice and accounting methods, lack of proper auditing, and failure to secure the support of wholesale houses because of scattered buying.

(3) *Unfavorable environment.*—Where a cooperative association has been thrust into a community which is naturally divided against itself through racial prejudice, interdenominational strife, excessive individualism, or where there is insufficient business to pay the expenses of a store, there can be little hope of success for the association.

(4) *Lack of proper legal safeguards.*—One cause of the failure of many different types of cooperative associations is the lack of proper legislation. Some of the stores organized in the early days under corporation laws have had their stock centered in the hands of a small body of members who have controlled the association in their own interests, and have distributed among themselves whatever surplus accrued as dividends upon capital stock. This means the entire failure of the association from the cooperative standpoint. On the other hand, cooperative laws have been passed by many States that offer no adequate safeguards in the form of preliminary investigation and subsequent inspection. On account of the semipublic nature of the cooperative business, it is believed that both of these safeguards are essential to success.

APPENDIX.

NOTES ON THE PAYMENT OF TRADE DIVIDENDS.

I. Stores having paid dividends regularly out of profits (17) :

1. Organized 1905. Had missed paying trade dividend only once in 10 years.
2. Organized 1908. 1909, 21 per cent; 1910, 16 per cent; 1911, 10 per cent; 1912, 10 per cent; 1913, 8 per cent; 1914, doubtful. One of the mistakes of the first years was the payment of too large dividends.
3. Organized 1912. Interest on stock has been paid regularly. Dividends: 1911, 10 per cent; 1912, 6 per cent; 1913, 14 per cent; 1914, 12 per cent.
4. Organized 1911. Seven per cent interest paid regularly. Dividends: 1911, \$1,734.30; 1912, \$8,140.52; 1913, \$9,170.59; 1914, \$9,914.30.
5. Organized 1912. Made large profit every year, and paid interest and trade dividends regularly.
6. Organized 1904. Stock now worth \$140. Has paid interest and dividends regularly.
7. Organized 1908. Dividends: 1911, 2 per cent; 1912, 2½ per cent; 1913, 3 per cent; 1914, 3 per cent. Surplus, \$4,339.
8. Organized 1890. Interest and dividends paid regularly for 25 years. Total, \$1,277,865.94. Range from 9 to 13 per cent on purchases, to members only.
9. Organized 1889. Forty-nine semiannual dividends in 25 years; 3 per cent purchase dividend to all. Regular stock dividends to members only.
10. Organized 1893. Twenty-two years old. Trade dividend every year from 3 to 5 per cent, members only; \$6,600 surplus and undivided profits.
11. Had paid dividends regularly; 1913, 5 per cent; 1914, 6 per cent.
12. Organized 1912. Paid \$2,300 dividend 1913; making good profit.
13. Organized 1897. Paid 12 per cent dividends and 6 per cent interest in 1914; very successful.
14. Organized 1890. Except first year had paid dividends ranging from 6 to 10 per cent.
15. Organized 1913. Claims regular payment; business seems prosperous; no specific figures.
16. Paid 5 to 15 per cent dividend every year for 6 years; had large surplus.
17. Organized 1906. Trade dividends have been paid every year until last year, 3 to 5 per cent. Had a very small-surplus.

¹ The numbers are not the same as in Table X.

II. Stores having paid dividends irregularly out of profits (3) :

18. Paid dividends 1903, 1904, 1905; surplus, \$33,000.

19. Organized 1912. Auditor in 1914 advised not paying dividends because of large amount of subscribed capital unpaid, although profit was made.

20. Organized 1876. Originally paid dividends, but not since 1912.

III. Stores paying trade discount instead of dividends (3) :

21. Organized 1912. Discount of 5 per cent if account is paid in full within 30 days.

22. Organized 1911. Discount of 5 per cent if account is paid in full within 30 days.

23. Discount of 5 per cent to members if account is paid in full within 30 days.

IV. Stores having paid dividends out of capital (7) :

24. Organized 1913. Paid 5 per cent in 1915 out of capital. Report shows that in reality there was a deficit.

25. Organized 1910. Only one dividend has been paid, in 1911. Deficit, \$1,200, in 1914.

26. Organized 1913. Paid first year only. Suffered from overexpansion, but is now in fair way to succeed.

27. Organized 1912. Dividends paid first two years out of capital; deficit, \$5,000.

28. Organized 1912. Paid 6 per cent first year only; present deficit, \$5,000.

29. Organized 1903. Paid several large dividends out of capital; now in hands of receiver.

30. Organized 1903. Paid dividends regularly 1906 to 1912 out of capital. Failed to take into consideration bad debts and depreciation, with resultant false showing. "One of the great mistakes of the store." Surplus, \$800.

V. Stores paying only stock dividends (3) :

31. Organized 1876. Average 70 to 10 per cent annually on stock.

32. Average for last five years is 10 per cent to members. None to nonmembers. Now a regular stock company, but said to retain "the cooperative spirit."

33. Organized 1889. Now a regular stock company. Had failed to make profit only one year. Stock now worth 500 per cent, because the profits of five years were allowed to remain in the business. Twenty yearly dividends on stock only have been paid, ranging from 6 to 50 per cent.

VI. Stores having paid no dividends (14) :

34. Organized 1913. No dividends paid "on account of disloyalty of members."

35. Organized 1910. No dividends have been paid. In 1914 had a \$4,000 deficit.

36. Organized 1910. Neither interest nor dividends have been paid; planning to reorganize as stock company.

37. Organized 1912. On verge of bankruptcy.

38. Organized 1914. Hopes to pay 6 per cent to members and 3 per cent to nonmembers; very conservative management.

39. Organized 1912. No dividends paid, "due to excessive credit." Expect to pay one in the near future; 6 per cent interest paid on capital.

VI. Stores having paid no dividends—Continued.

40. Organized 1911. No dividend paid. "Victim of early mismanagement," but now said to be on road to success.
41. Organized 1912. No dividends paid. Has a considerable deficit.
42. Organized 1877. No dividends or interest paid, bad management.
43. Organized 1909. Failed twice, due to mismanagement. No dividends have been paid.
44. Organized 1912. No dividends; business in unsatisfactory condition.
45. Organized 1903. No dividends paid, due to excessive credit and loss by fire.
46. Six years ago had large deficit. No dividends. Is building up surplus now, and appears to be in prosperous condition.
47. Organized 1912. No reliable information, but appears to be in very unsatisfactory condition.



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WM. A. TAYLOR, Chief

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PROFESSIONAL PAPER.

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PEACH SCAB AND ITS CONTROL.¹

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INTRODUCTION.

Peach scab (*Cladosporium carpophilum* Thüm.) is a parasitic disease which affects the fruit, twigs, and leaves of the host (*Amygdalus persica*). It manifests itself on the fruit as small, circular, olivaceous to black spots, which frequently become confluent over considerable areas and seriously detract from the appearance, quality, and value of the marketable product. On the twigs and leaves it occasions less damage, producing small superficial injuries, which are described in detail later. In the United States, east of the Rocky Mountains, it occurs generally, and unless controlled it may cause serious financial

¹ The laboratory studies upon which this paper is based were conducted in field laboratories at Hart, Mich., in the season of 1911, at Cornelia, Ga., in the seasons of 1912 and 1913, and in the laboratory of plant pathology of the University of Wisconsin in the winters of 1911 to 1914 and the summer of 1914. The field work was carried on in cooperation with growers in commercial orchards at Hart, Mich., in 1911, and at Cornelia, Ga., in 1910, 1912, and 1913.

losses in practically all of the important peach-producing districts in this area.

The disease was first reported from Klosterneuberg, Austria, by Von Thümen (1877),¹ who observed its occurrence upon the fruit of the peach and briefly described the associated fungus as *Cladosporium carpophilum* sp. nov. The same author (1879, p. 13-15) emended his original description of the fungus and published notes concerning the occurrence, description, and economic importance of the malady. The disease received little further attention until its occurrence in America was reported by Arthur (1889, p. 5-8), who noted its prevalence in Indiana and described the fruit lesions and the associated fungus, citing the work of Von Thümen. Peach scab, however, was not unknown to American mycologists prior to this time, since the herbarium of the New York Botanical Garden and the Pathological Collections² of the Bureau of Plant Industry contain specimens collected by F. S. Earle, Cobden, Ill., 1881³ (on fruit) and 1887^{3,4} (on leaves), and by A. B. Langlois, Mississippi, 1886^{3,4} (on fruit). Pammel (1892, p. 100) reported that Galloway, in unpublished notes, had recorded the occurrence of the "peach fungus" (*Cladosporium carpophilum*) on peach leaves. Halsted (1895, p. 329-330) described what he considered to be scab injury upon peach leaves. A study of his description and illustrations, however, makes it appear conclusive that he failed to differentiate true scab injury from other foliage troubles. Taft (1894, p. 57) reported the scab fungus as attacking fruits, leaves, and tender shoots of the peach. He gave no details, however, concerning the injury on twigs and leaves. Sturgis (1897) noted a fungus, which he reported as conforming morphologically to the description of *C. carpophilum*, associated with twig injuries of the peach, almond, and apricot. He concluded that the fungus was *C. carpophilum* and that it was the causal agent of the trouble. He reported, however, no cultural studies or infection experiments. Clinton (1904, p. 340-341) briefly described scab injuries on peach fruit, twigs, and leaves.

Selby (1898 and 1904), beginning in 1895, conducted an extensive series of peach-spraying experiments, from which he concluded that scab may be controlled by the use of Bordeaux mixture. A large number of similar tests have been made with Bordeaux mixture of various formulas and methods of preparation, but the toxicity of this fungicide to the foliage has prevented its coming into general use in the United States as a summer spray for peaches. Scott (1907 and

¹ Bibliographic notations in parentheses refer to "Literature cited," pp. 64-66.

² The writer wishes to express his indebtedness to the curators of these herbaria for their kindness in making these records available and in sending him material which enabled him to verify the identification of each of these collections.

³ In the herbarium of the New York Botanical Garden, New York.

⁴ In the Pathological Collections of the Bureau of Plant Industry, United States Department of Agriculture.

1908) obtained promising results from the use of self-boiled lime-sulphur for peach-scab control. The same author (1909) reported that this fungicide satisfactorily controlled the disease without objectionable foliage injury and recommended its use in commercial orchards. These results have been confirmed by Scott and Ayres (1910), Scott and Quaintance (1911), and other investigators.

Thus, while peach scab has received a considerable amount of attention from botanists and plant pathologists, the status of knowledge of the disease has remained fragmentary and incomplete. No attempt at a thoroughgoing study of the malady appears to have been undertaken, previous work having been confined chiefly to descriptions of *Cladosporium carpophilum* and of the injuries which it induces, to field observations, and to the empirical development of control measures. Consequently, the etiology of the disease has not been scientifically determined and the detailed life history of the causal organism in relation to pathogenesis and to control measures has remained obscure.

The purpose of the investigations reported in this bulletin has been to further the understanding of the nature, cause, development, and control of peach scab. Accordingly, the effort has been directed along four correlated major lines of study, viz, (1) the disease, (2) the causal organism, (3) the detailed life history of the causal organism in relation to pathogenesis, and (4) control measures.

Studies of the relationships of peach scab to similar diseases of other stone fruits have not been included in this problem, though such investigations are now under way. Consequently, only peach scab will be considered in this bulletin.

THE DISEASE.

GEOGRAPHIC DISTRIBUTION.

In order to supplement the available published data concerning the geographic distribution of peach scab in the United States, a brief questionnaire was recently sent to the authorities¹ of each State agricultural experiment station. The disease was reported from the following States: Alabama, Arkansas, California, Colorado, Connecticut, Delaware, Florida, Georgia, Idaho, Illinois, Indiana, Iowa, Kansas, Kentucky, Louisiana, Maryland, Massachusetts, Michigan, Mississippi, Missouri, Nebraska, New Hampshire, New Jersey, New York, North Carolina, Ohio, Oklahoma, Pennsylvania, Rhode Island, South Carolina, Tennessee, Texas, Virginia, and West Virginia.

In foreign countries, scab appears to occur practically wherever the peach is grown intensively under normal conditions. However, since peach production abroad is relatively of much less importance

¹ The writer wishes to make grateful acknowledgment of his indebtedness to all who cooperated in compiling these data.

than in the United States, the disease has received only minor attention from foreign writers. Von Thümen (1877) reported its occurrence in Austria; Cobb (1894, p. 385-386), in Australia; Craig (1898, p. 40), in Canada; Oudemans (1901, p. 388), in Holland; Sorauer (1908, p. 252), in southern Europe; and Evans (1911, p. 696), in South Africa.

ECONOMIC IMPORTANCE.¹

Badly scabbed fruit is seriously reduced in market value (1) by its unsightly appearance (Pl. I, figs. 1 and 2); (2) by its lack of uniformity in size, shape, and evenness of ripening; (3) by the cracking of individual or of confluent lesions (Pl. I, fig. 1, and Pl. II) and the consequent increment in destructive fungal and bacterial invasions—notably brown-rot (*Sclerotinia cinerea* (Bon.) Schröt.) (Pl. II, upper figure); and (4), in severe cases, by its impaired flavor. Further loss may be occasioned by the premature shedding or shriveling of fruits which are badly scabbed about the attachment of the peduncle.

Many writers have reported severe economic losses from peach scab. Selby (1904, p. 63) recorded heavy losses in Ohio. Rolfs (1909, p. 66) states—

At least 60 per cent of the Elberta fruit on the station ground during the season of 1906 was ruined by this organism [*Cladosporium carpophilum*]. The loss was even greater on a number of other varieties.

Scott and Ayres (1910, p. 14) write—

The damage done by this disease is apparently not fully realized by peach growers. Scab spots are so common on the peach that most of the eastern growers have come to take the disease as a matter of course and scarcely realize that their fruit is bringing 25 per cent less in the market than the same fruit free from scab would bring. * * * In many localities it practically prohibits the growing of certain varieties * * * and the growers have been obliged to confine their plantings of such late varieties as Bilyeu and Salway to the high ridges in order to avoid scab.

Scott and Quaintance (1911, p. 10-11) say—

If the loss in the orchard and the reduction in market value are both considered, it seems evident that a loss of 10 per cent of the total value of the peach crop in the eastern United States is caused by peach scab.

In order to supplement the data from published records and personal observations, an inquiry concerning the economic importance of the disease in the various States was included in the questionnaire referred to on the preceding page. The answers showed a consensus of opinion that, unless controlled, the disease may occasion serious losses in practically every important peach-producing State east of the Rocky Mountains.

In formulating a more concrete conception of the economic importance of the disease, it is of interest to refer to the estimates of the latest census report² from which the data in Table I are taken.

¹ See estimates and notes by Mr. M. B. Waite, p. 45-46.

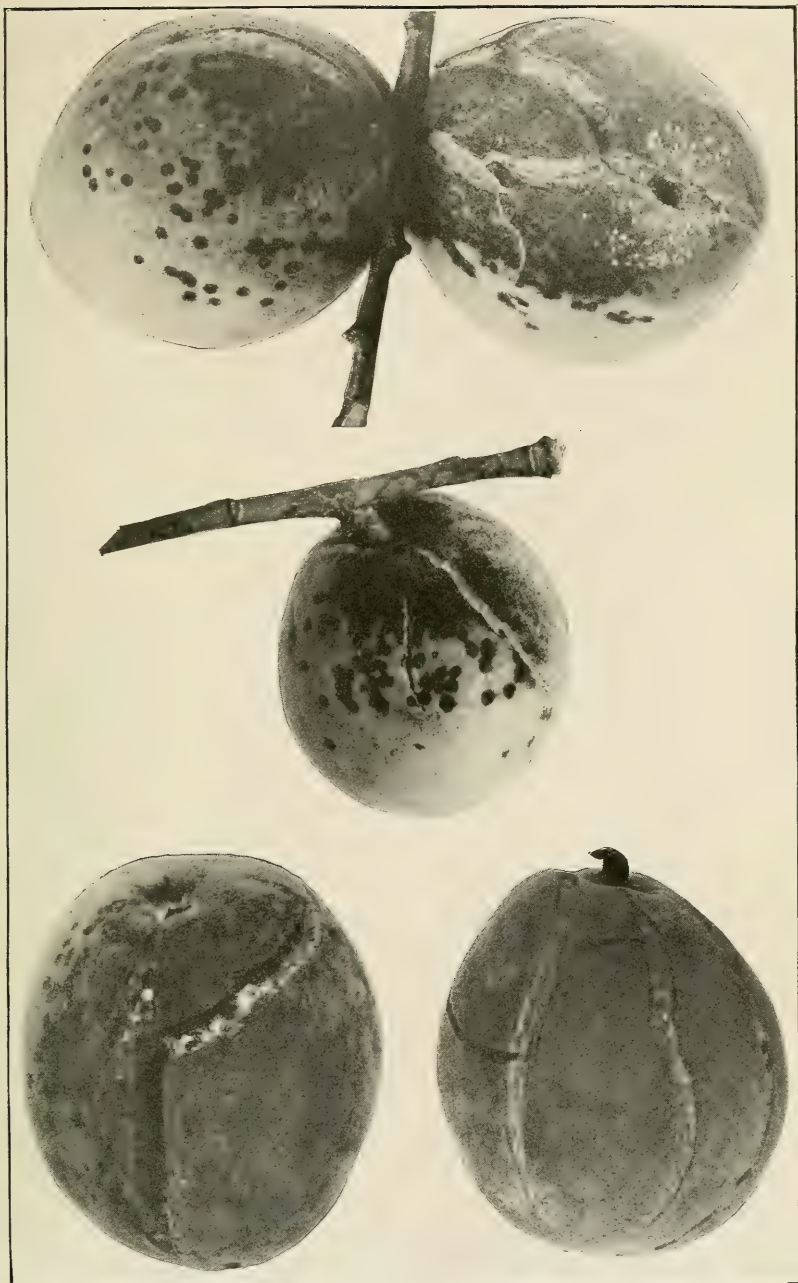
² Thirteenth Census of the United States . . . v. 5, Agriculture, 1909-10, p. 711, tab. 133. 1913.



A. Hoehn & Co. Baltimore.

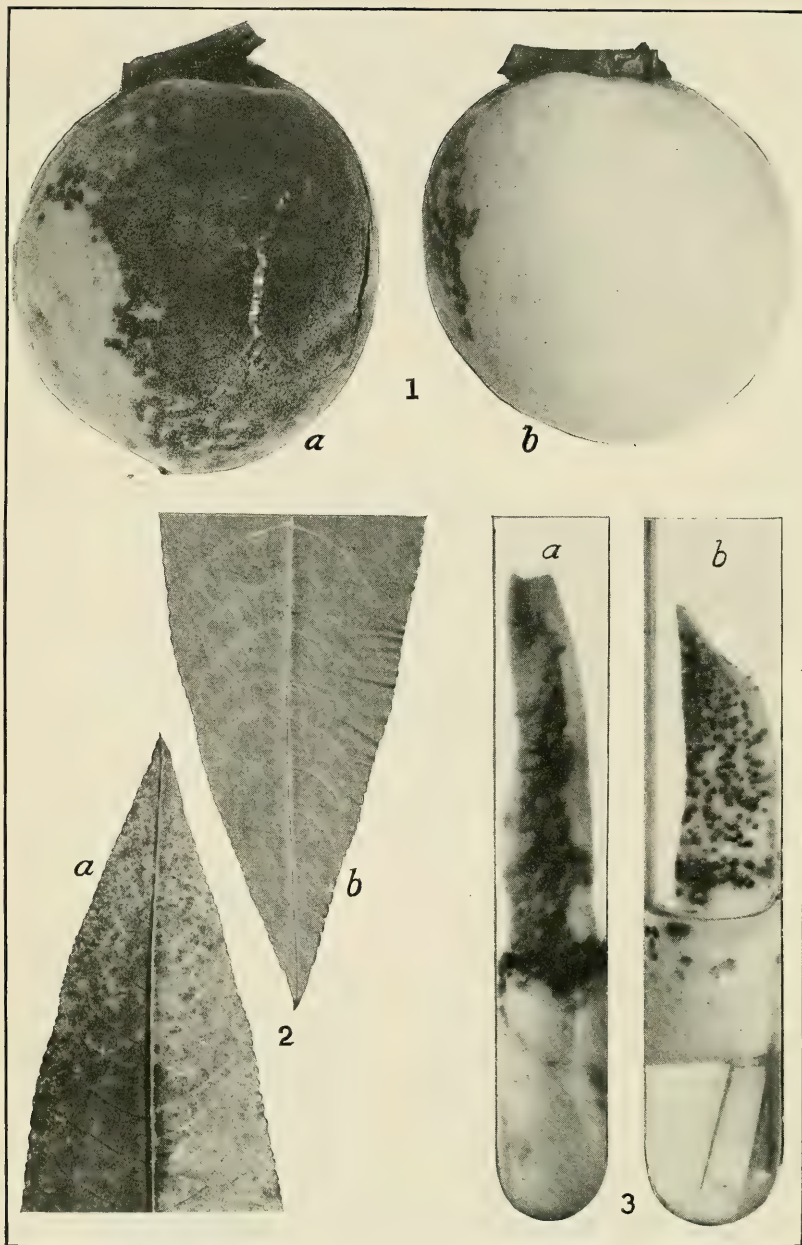
PEACH FRUITS, TWIGS, AND LEAF ATTACKED BY *CLADOSPORIUM CARPOPHILUM*.

FIGS. 1 AND 2.—Badly diseased Elberta fruits from Chevy Chase, Md., August 6, 1915 (about a week before harvest). FIG. 1.—Cracking of the diseased area. FIG. 2.—Close proximity of twig lesions to the infected area of the fruit. FIGS. 3 AND 4.—Early stages of infection on twigs of 1-year-old Early Crawford trees from inoculation experiments at Madison, Wis., August 6, 1915. Painted 40 days after inoculation. FIG. 5.—Typical natural infection on an Elberta twig from Chevy Chase, Md., September 16, 1915. FIG. 6.—Well-developed lesions on an Elberta twig in the spring following infection. FIG. 7.—Badly diseased leaf of a Heath tree from Chevy Chase, Md., September 16, 1915.



ELBERTA PEACHES BADLY ATTACKED BY *CLADOSPORIUM CARPOPHILUM*.

The upper figure shows brown-rot following scab. From Chevy Chase, Md., August 6, 1915, about a week before harvest. (Natural size.)



CLADOSPORIUM CARPOPHILUM ON PEACH FRUIT AND LEAF AND IN CULTURE.

FIG. 1.—Badly diseased Elberta fruit, showing typical distribution of infection: *a*, Surface most exposed to wetting, abundantly infected; *b*, surface least subject to wetting, no disease evident. From Chevy Chase, Md., August 6, 1915. (Natural size.) FIG. 2.—Distal portion of a badly diseased Heath leaf, showing typical distribution of the infection: *a*, Lower surface, abundantly infected; *b*, upper surface, no infection evident. From Chevy Chase, Md., October 5, 1915. (Nearly natural size.) FIG. 3.—Cultures: *a*, On steamed bean pod; *b*, on steamed potato cylinder. Photographed when cultures were 30 days old. (Natural size.)

TABLE I.—*Peaches and nectarines—trees, production, and value in the United States.*

Geographic division.	1910		1909		1899
	Trees of bearing age.	Trees not of bearing age.	Production.	Value.	Production.
	<i>Number.</i>	<i>Number.</i>	<i>Bushels.</i>	<i>Dollars.</i>	<i>Bushels.</i>
United States	94,506,657	42,266,243	35,470,276	28,781,078	15,432,603
Groups of States:					
New England.....	723,810	572,237	406,903	632,411	104,737
Middle Atlantic.....	6,056,690	5,759,925	3,201,493	4,018,034	1,231,242
Eastern North Central.....	11,035,119	6,972,375	5,120,841	5,172,957	716,670
Western North Central.....	13,265,526	2,582,028	1,643,257	1,250,944	212,932
South Atlantic.....	20,583,445	6,137,901	5,571,628	4,888,459	1,412,471
Eastern South Central.....	10,312,768	3,865,232	5,775,799	4,098,776	549,226
Western South Central.....	22,284,966	8,734,552	3,279,545	2,761,044	2,192,353
Mountain.....	1,605,285	1,696,111	940,168	1,071,446	267,365
Pacific.....	8,639,048	5,945,882	9,530,642	4,887,007	8,745,607

Though the nectarine is represented in these figures, it is relatively so unimportant that for purposes of rough estimation it may be left out of consideration. According to these estimates, in 1910 there were in the United States 94,506,657 bearing peach and nectarine trees, which, during the preceding year, yielded a crop valued at \$28,781,078. The greater portion of the trees in the South Atlantic, eastern South Central, western South Central, eastern North Central, and Middle Atlantic States, estimated at 70,272,988, are in sections subject to serious losses from scab. Those of the New England and western North Central States, numbering 13,989,336, with the exception of those in the more southern areas, as Missouri (6,588,034) and Kansas (4,394,894), are generally distinctly less seriously affected, while the 10,244,333 trees of the Mountain and Pacific States, only 10.8 per cent of the total number, may be classified as free from economic injury by scab.

Inasmuch as any accurate computation of the losses occasioned yearly by the disease would of necessity be based upon such undeterminable factors as actual losses and expenditures for preventive treatments, a concrete estimate is scarcely profitable. The experience of the years immediately preceding the development of control measures, however, emphasizes the potential damage of the disease. During this period, owing to the combined ravages of brown-rot and scab, commercial peach growing in the southern portions of the United States suffered a severe check, while even in the eastern and central sections plantings of certain varieties had to be discontinued or confined to the higher altitudes in order to escape scab. With the improved standards of excellence which successful summer spraying has instituted and with the cumulative development of the disease in unsprayed orchards, it is evident that if no scab control were available the disease would be a serious menace to successful commercial peach culture in many sections of the southern, eastern, and central United States.

DESCRIPTION.

On fruit.—The earliest macroscopic evidences of infection upon the green surfaces of the fruit appear as imperfectly defined, greenish to olivaceous, circular areas, usually less than half a millimeter in diameter. This effect is due to the appearance of the olivaceous conidiophores and conidia of the fungus among the hairs of the fruit. Upon blush surfaces, the early development of olivaceous color may be accompanied or preceded by the disappearance of the normal pink from the invaded areas, which remain much paler than normal until masked by the development of the fungus. In such cases a narrow peripheral zone of pale or yellowish green may mark the advance of each diseased area. The developing lesions gradually become larger, darker, and more clearly defined, owing to the death and disappearance of many of the obscuring hairs of the fruit and to growth and pigmentation of the fungus. When fully developed they are fairly well defined, circular, olivaceous to black areas with an average diameter of 2 to 3 millimeters, though under very favorable conditions they may attain a diameter of 4 or 5 millimeters (Pl. I, figs. 1 and 2, and Pl. II). The direct injury is superficial, involving at most only a few layers of cells, which typically become separated from the adjacent normal tissues by the formation of cork. The infections occur practically exclusively upon the areas which are subject to thorough wetting. The lesions are, thus, generally most abundant about the peduncle and upon the upper portion of the wettable¹ surface (Pl. III, fig. 1, *a*). They may be more or less uniformly scattered over the entire wettable surface, or they may be so abundant as to become confluent over large patches, frequently covering practically one-half of the surface of the fruit. The protected surfaces of even the most severely attacked fruits are usually free from infection (Pl. III, fig. 1, *b*). As the peaches grow rapidly just prior to maturity, the corked areas can not expand so readily as the normal tissues. This condition may result in mere inequalities of development between badly diseased and normal areas, but more commonly the growth stresses occasion the cracking of the cork layers. These cracks may appear upon individual lesions as small rifts extending slightly into the flesh, but upon very badly affected specimens they may extend the length of the fruit and penetrate to the pit (Pl. I, fig. 1). Badly scabbed fruits do not ripen evenly and are frequently inferior in flavor. Those which are severely scabbed about the attachment of the peduncle may be shed prematurely.

¹ In the earlier stages of development of the peach, its hairy surface is very resistant to wetting. With growth and weathering, however, that portion which is exposed to the action of falling meteoric water becomes more easily wettable, while the area protected from such action, usually the opposite side of the fruit, remains difficultly wettable throughout the important period of scab infection. For the sake of convenience, these areas subsequently will be referred to as "wetable" and "protected," though it should be realized, of course, that these terms are relative, not absolute.

On twigs.—On tender young green twigs, the first macroscopic evidences of infection, typically, are barely visible, more or less imperfectly defined, very slightly raised, irregularly circular to oval areas, almost indistinguishable in color from the surrounding normal surfaces. As the lesions develop, their central areas become light brown, and later darker brown, and each is bordered by a slightly raised peripheral zone, usually about half a millimeter wide and of approximately the normal green color. The coloration and zonation, however, may vary considerably with such factors as the age and character of the twig, seasonal conditions, and the stage of development of the disease. At the end of the growing season, well-developed lesions appear as smooth, irregularly oval, light-brown to dark-brown areas of normal elevation, with slightly raised purplish to dark-brown borders, which usually vary from one-half to 1 millimeter in width and shade off peripherally into the color of the surrounding normal surface (Pl. I, figs. 3 to 5, and Pl. IV, fig. 2). Such lesions usually measure 3 to 5 by 5 to 8 millimeters, the greater development being parallel to the axes of the twigs. The injury is superficial, involving only a few layers of the cells, the diseased areas becoming separated from the adjacent normal tissues by the formation of cork layers. Under favorable conditions, conidiophores, which bear typical conidia, may be produced upon the surfaces of the infected areas at any time after the lesions become macroscopic. During the summer and fall following the infection, the conidiophores are ordinarily produced singly, and seldom in such quantity as to be macroscopically evident. In the following spring, however, they are produced abundantly in olivaceous tufts. These sporiferous tufts may develop over the entire surfaces of the lesions, or they may be confined to peripheral zones, usually 1 to 2 millimeters in width, leaving the grayish brown central areas bare (Pl. I, fig. 6, and Pl. IV, fig. 3). Such lesions may enlarge slightly during the spring and early summer of the second season. As the summer progresses and the bark is differentiated, however, they gradually begin to lose their identity. By the third summer, they usually become indistinguishable, while the fungus rarely survives the second winter. Lesions on water sprouts or very rapidly growing twigs may lose their identity with the rapid cork formation of the first summer. Twig infections are miscellaneously distributed upon the wood of the current year's growth. They may be sufficiently numerous to become confluent and form irregularly shaped lesions, which may attain a length of several centimeters. On account of their superficial nature, however, they rarely cause appreciable injury to the twigs.

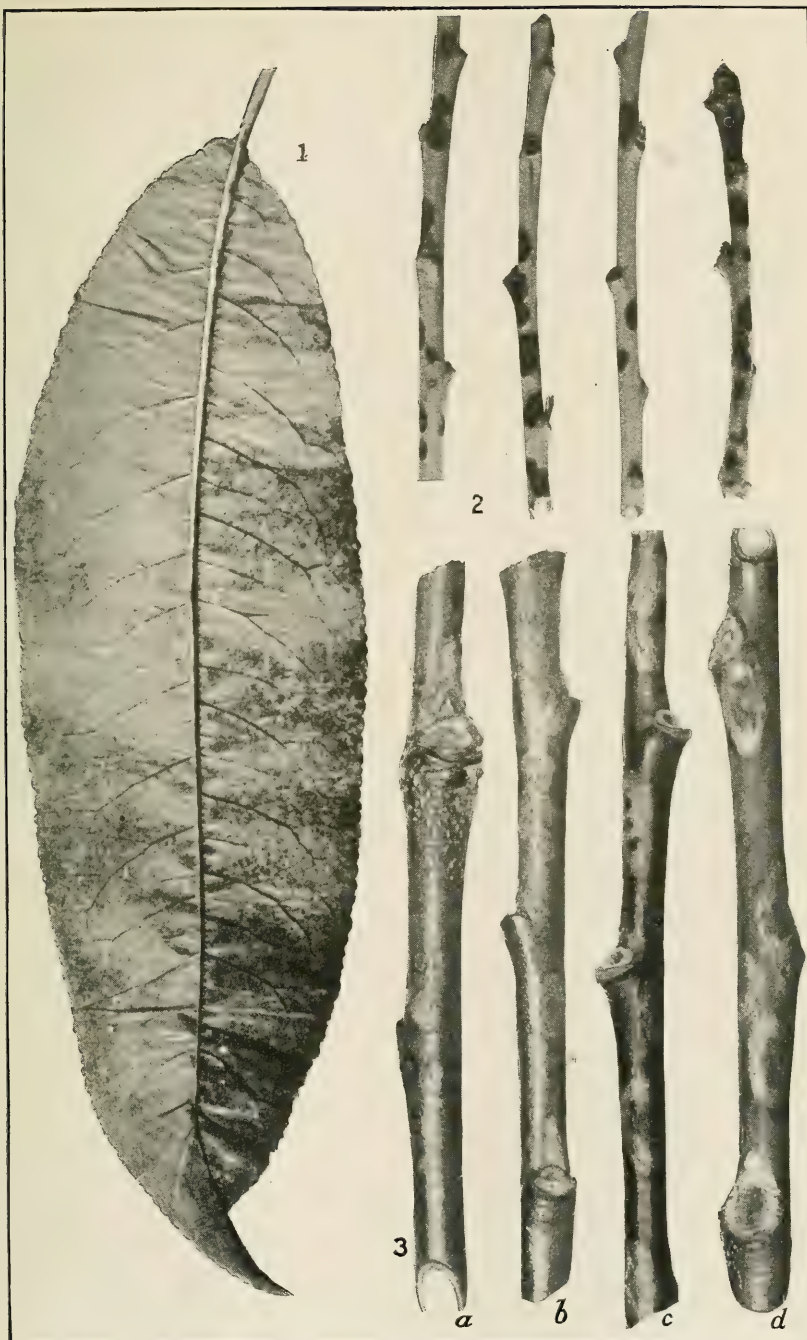
On leaves.—The first macroscopic evidences of infection appear upon the lower surfaces of the leaves as indistinct, imperfectly defined, somewhat angular to circular discolored areas, usually one-half to 1 milli-

meter in diameter. The color of the affected surface may be a pale green, almost indistinguishable from the normal, or it may vary to light brown or pinkish purple. The true color, however, is frequently modified or masked by an abundant development of olivaceous conidiophores and conidia. These are usually present in greater or less numbers when the infection first becomes macroscopic. When conditions especially favor their development, they may be borne in sufficient quantities to give a dark-green color to the lesions and to constitute their most conspicuous character. On the leaf lamina the fully developed lesions are somewhat angular to irregularly circular. Their average diameter is 1 to 2 millimeters, though in rare cases they may attain a diameter of 5 or 6 millimeters (Pl. I, fig. 7, and Pl. IV, fig. 1). On the petioles and midribs they are usually much longer and narrower, generally measuring 3 to 8 by one-half to 1 millimeters. The color of the blotch proper may vary from light brown to dark brown, or it may be pinkish purple. The demarcation remains indistinct and the elevation is usually unchanged, except in extreme cases, when the lamina above the larger lesions may become convex below and correspondingly concave above. When the lesions first appear, no evidence of disease is visible upon the upper surfaces of the leaves. In later stages, however, the tissues above and immediately around the affected areas may lose some or all of their green color and become pale yellow or purplish. In extreme cases such areas may die, but ordinarily no definite leaf spotting is induced. The lesions may occur miscellaneously scattered over the lower surfaces of the leaves and upon the petioles, or they may develop in such abundance as to become confluent and form irregular patches (Pl. III, fig. 2). The infection appears to occur with equal readiness on the petioles, midribs, veins, and leaf lamina. It was demonstrated in the inoculation experiments that badly diseased leaves may turn yellow and fall, but the writer has rarely observed this condition as the result of natural scab infection.

PATHOLOGICAL HISTOLOGY.

Histological technique.—In killing material for histological work, several standard fixing agents were employed, viz, Flemming's weak, medium, and strong fluids, picro-formal, and chrom-acetic. The stains used were Flemming's triple, Haidenhain's iron alum-haematoxylin, Durand's haematoxylin-eosin, gentian violet, and safranin.

For most purposes, Flemming's medium fluid and the triple stain gave the best results. This combination not only stained the fungus well, but gave an excellent differentiation of fungus and host in twig and fruit lesions. The cuticle of the host remained practically colorless, while the dead epidermal and subepidermal cells took little stain, being yellowish green in the finished preparation. In sharp



PEACH LEAF AND TWIGS ATTACKED BY *CLADOSPORIUM CARPOPHILUM*.

FIG. 1.—Lower surface of badly diseased Heath leaf, showing abundant infection. From Chevy Chase, Md., October 5, 1915. (Natural size.) FIG. 2.—Badly diseased Elberta twigs. From Chevy Chase, Md., August 6, 1915. (Natural size.) FIG. 3.—Elberta twigs, showing lesions as they appear in the spring following infection, with abundant production of conidial tufts: *a* and *b*, Small lesions, evidently the result of late infection; *c* and *d* fully developed lesions. From Cornelia, Ga., May 31, 1912. (Magnified, $\times 2$.)

contrast, the fungal tissue took up the red and orange quite freely, while the dividing cells of the cork-forming layers stained a striking blue and the normal host cells below a bright red.

Fruit lesions.—In the early stages of fruit infection the slender, branching, hyaline, septate hyphæ of the fungus are found closely appressed to the inner walls of the irregular surface cells of the host. This early development is most abundant in the minute depressions about the bases of the hairs, where conditions seem to be particularly favorable for the development of the parasite (fig. 1). As the fungus becomes firmly established, conidiophores are produced, while the vegetative hyphæ branch and thicken until they may entirely cover the area of infection. The individual cells thicken and darken, while transverse and longitudinal divisions take place, often resulting in the formation of irregular fungal masses five or six cells in depth (fig. 2, *a*). This later development, too, is particularly abundant in the depressions about the bases of hairs.

As the fungus develops generally over the surface of the infected areas, the superficial host cells die and the lesions may be cut off from the

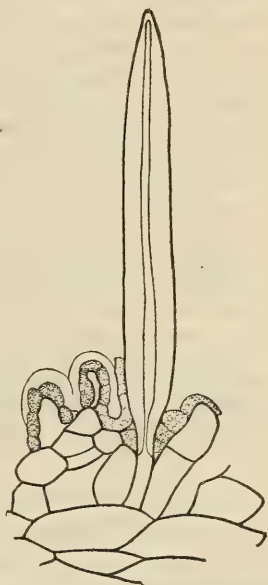


FIG. 1.—Section of a lesion from an Elberta peach fruit, showing the early development of the parasite about the base of a hair, in close contact with the inner walls of adjacent surface cells of the host. Camera-lucida drawing. (Magnified 465 times.)

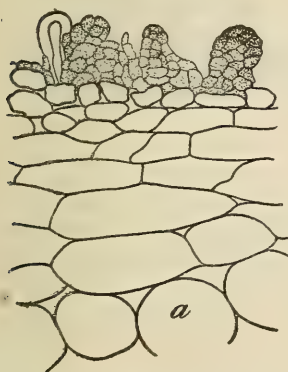


FIG. 2.—Sections of lesions from Elberta peach fruits: *a*, Shortly before cork formation; *b*, soon after cork formation. At the right the section extends nearly to the edge of the corky layer. Camera-lucida drawings. (Magnified 310 times.)

sound tissues below by the formation of protective layers of cork (fig. 2, *b*). These layers are formed as the result of tangential divisions of the subepidermal cells. Less frequently, transverse divisions occur. Cork formation is usually most vigorous in the third or fourth subepidermal layers and ordinarily extends slightly above and below this actively dividing region.

In the case of early varieties of peaches, the fruits usually mature before cork formation occurs. Upon later varieties, however, the

cork layers may be formed before the final rapid swelling of the fruit prior to its maturity. In such cases stresses are set up and cracks of varying sizes result. In many cases such openings are scarcely macroscopic, but on badly diseased fruits, where the spots have become confluent, the cracks may extend across an entire side of the peach and reach inward to the pit.

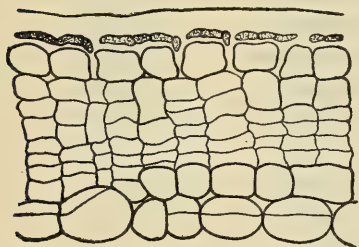


FIG. 3.—Longitudinal section of a lesion from an Elberta peach twig of the current year's growth, showing the early subcuticular development of the fungus and a very early stage of cork formation. Camera-lucida drawing. (Magnified 310 times.)

As the fungus develops, its ramifications become more general, its individual cells thicken, the underlying epidermal cells of the twig die, and the diseased areas are effectively cut off from the sound cortical tissues below by layers of cork cells. These corky layers are formed by means of tangential divisions of the subepidermal cells. It is not unusual, however, for the first division to be transverse, the daughter cells dividing tangentially. The two or three actively concerned hypodermal layers are, in each case, rapidly converted into a fairly uniform barrier of thin corky cells of meager protoplasmic content. As the lesions age and the epidermal cells become more and more disorganized, the outer layers of subepidermal cells die and turn brown.

After the advent of the dormant period of the host, the fungus continues to develop throughout the fall, mild periods of the winter, and the spring. The subcuticular hyphæ increase in diameter and in number until they form stromateoid layers which may extend over the entire lesions. While these structures may consist merely of single layers of cells, they are usually thicker, often developing into pseudoparenchymatous masses, six or eight cells deep (fig. 4).

With the vigorous subcuticular development of the fungus, the cuticle is often slightly raised and at times broken, while the remains

Twig lesions.—In the early stages of twig infection, slender, branching, hyaline, septate hyphæ of the fungus are found penetrating the subcuticular areas immediately exterior to the cellulose walls of the epidermal cells (fig. 3). As the fungus develops, its ramifications become more general, its individual cells thicken, the underlying epidermal cells of the twig die, and the diseased areas are effectively cut off from the sound cortical tissues below by layers of cork cells.

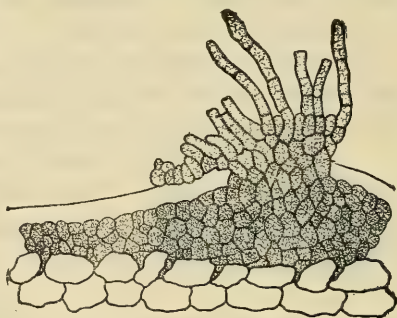


FIG. 4.—Longitudinal section of a lesion from an Elberta peach twig of the preceding year's growth, showing the abundant subcuticular development of the fungus and the vigorous production of conidiophores in the spring following infection. The host cells, which were badly disorganized, are semidiagrammatically represented. Camera-lucida drawing. (Magnified 310 times.)

of the dead epidermal cells are compressed inward in extreme cases until their identity is almost lost. In such cases the fungus often grows down between the epidermal cells, and occasionally hyphæ penetrate the intercellular areas of the first subepidermal layer.

After the protective corky layers are fully formed, no further pathological anatomical changes occur. As the bark forms and roughens with the second year's growth of the twigs, the cuticle of the diseased areas partially sloughs off; and, as the bark thickens with subsequent development, the lesions gradually lose their identity.

Leaf lesions.—In the early stages of leaf infection, the slender hyphæ of the fungus are found between the cuticle and the cellulose walls of the epidermal cells of the lower (dorsal) surface. As the fungus develops, its ramifications become more abundant, and under favorable conditions conidiophores and conidia are produced. Its ultimate development, however, is much less vigorous than upon twigs or fruit, no pseudoparenchyma having been observed on the leaf lamina. The invasion appears to be merely subcuticular and the fungus is very inconspicuous, even in well-stained preparations. The chlorophyll usually disappears from the mesophyll cells immediately adjacent to the invaded areas, while in extreme cases this abnormality extends into the leaf lamina to such an extent that the areas above the lesions appear distinctly yellow or purplish when viewed from the upper (ventral) surface.

When infection occurs upon the petioles or larger veins, corky layers similar to those described for fruit and twig lesions are formed. In such cases the development of the fungus is distinctly more vigorous than on the leaf lamina, but much less so than on fruits and twigs.

THE CAUSAL ORGANISM.

TAXONOMY.

Von Thümen (1877), at Klosterneuberg, Austria, first described the peach-scab fungus, naming it *Cladosporium carpophilum*. Two years later the same author (1879, p. 13) emended his original description. Saccardo (1886, p. 353) gives Von Thümen's emended description in slightly abbreviated form. Arthur (1889, p. 7) reviews the references cited above and gives a translation of Von Thümen's emended description. Oudemans (1901, p. 388) describes as *Fusicladium carpophilum* Oud. a fungus growing on fallen young peaches. He lists as a synonym *Cladosporium carpophilum* Thüm., but neither gives Von Thümen credit as authority for the specific name nor states reasons for transferring the fungus to the genus *Fusicladium*. Aderhold (1900, p. 541-549; 1901, p. 656-657), after extensive investigations, concluded that *Fusicladium cerasi* (Rbh.) Sacc. should be referred to the genus *Cladosporium*. On comparing this

fungus with *Cladosporium carpophilum* Thüm. from peach fruit from America, he found only minor morphological differences, but obtained inconclusive results from cross-inoculation experiments. Though he does not formally conclude that these organisms are specifically identical, he expresses the personal conviction (1901, p. 657) that they are "ein und denselben Pilz" and calls attention to the fact that Pammel (1895, p. 207) and Selby (1897, p. 118) considered *Cladosporiums* associated with cherry and plum scab in America to be *Cladosporium carpophilum* Thüm. If Aderhold were correct in his belief, it would follow that *Cladosporium carpophilum* Thüm. should become a synonym of *Cladosporium cerasi* (Rbh.) Aderh., which in turn the same investigator (1900, p. 544) considers to be the imperfect stage of *Venturia cerasi* Aderh. The data which have been presented, however, fail to convince the writer that the organisms in question are identical. Therefore, until further evidence is adduced, he accepts the name *Cladosporium carpophilum* Thüm. for the peach-scab parasite.

While the contributions which have been made to the knowledge of *Cladosporium carpophilum* since Von Thümen's (1879) description make desirable certain further emendations, it is the belief of the writer that, in order to avoid unnecessary taxonomic complications, these should not be made until the relationships of the *Cladosporiums* on the stone fruits have been further determined. Meanwhile, Von Thümen's (1879, p. 13) description, which is quoted below, is in most essentials clear-cut and accurate.

Cl. maculas orbiculares, saepe confluentes, viridi-nigricantes, annulatas formans; hyphis brevibus, erectis, flexuosulis, continuis vel interdum septatis, subramosis, tenuibus, 4 mm. crassis, fuscis; sporis fuscoideo-ovatis, utrinque obtusiusculis vel raro vertice subacutatis, rectis, non vel obscure uniseptatis, diaphanis, 20 mm. long., 5-6 mm. crass., dilute fusciscentibus.—Thümen. l. c. emend.

In *Persicae vulgaris* Mill. fructibus maturis, epidemice.—Austria inferior (Thümen).

MORPHOLOGY.

Mycelium.—The morphological characters of the mycelium vary much with conditions. The very young hyphae are delicate, hyaline, branched, and septate. As the fungus develops, however, the diameter of individual cells normally increases, transverse and, more rarely, longitudinal divisions occur, and the walls of the more exposed cells thicken and become olivaceous. On the fruit lesions this growth may give rise to pseudoparenchymatous fungal masses, while a like development may occur beneath the cuticle of the twigs (figs. 2 and 4). In culture, stromateoid masses develop (Pl. III, fig. 3), the individual cells becoming much enlarged and often rounded, giving an irregularly moniliform appearance to the mycelial threads. In old cultures the mycelium tends to break up into its component cells, which under favorable conditions are capable of putting out vigorous hyphae. In all of these stromateoid structures the walls of

the more exposed cells thicken and darken and the individual cells may assume the characters of chlamydospores (fig. 5, *d* and *e*). On old cultures on steamed peach twigs or certain agar preparations, small, irregularly rounded to distinctly elongated, olivaceous, sclerotioid masses, usually less than one-third of a millimeter in diameter, may be found. The outer cells of these bodies are thick walled and olivaceous and frequently bear conidiophores. The inner cells are thin walled and colorless, with an abundant content of oily material.

Conidiophores.—The conidiophores (fig. 5, *a*, *b*, and *c*) are short, erect, more or less flexuous, one to several septate, rarely branched, olivaceous hyphæ, distinctly enlarged at the base and often tapering irregularly toward the apex. Their dimensions vary with conditions, though in nature they are fairly uniform during the early stages of sporulation. The conidia are produced acrogenously, beginning usually when the sporophores are about 30 to 35 μ long. The conidiophores elongate apically as conidia are developed, the places of attachment of detached spores being marked ordinarily by small wartlike processes or by geniculations on the sporophores. The extent of this type of elongation, which is quite variable, determines the ultimate length of the conidiophores. On the overwintered twig lesions the conidiophores borne from the subcuticular stromateoid fungal masses occur typically in tufts (fig. 4), and tend to be somewhat shorter and thicker than those occurring elsewhere in nature. On the fruit they grow much longer, often attaining a length of 90 to 100 μ . On leaf infections and twig lesions of the current year they tend to be somewhat more erect and less flexuous than on fruit or overwintered twigs. In culture there is much greater variation, the sporophores ranging from undifferentiated hyphæ to abnormally long, slender filaments. Measurements of conidiophores are summarized in Table II.

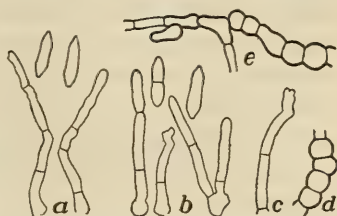


FIG. 5.—*Cladosporium carpophilum*: *a*, Conidiophores and conidia from fruit lesions; *b*, conidiophores and conidia from twig lesions; *c*, conidiophore from leaf lesion; *d*, and *e*, fragments of mycelium from Lima-bean agar culture, showing development of chlamydospores. Camera-lucida drawing. (Magnified 485 times.)

TABLE II.—Measurements of conidiophores of *Cladosporium carpophilum*.

Source.	Number measured.	Average measurements (microns).		Source.	Number measured.	Average measurements (microns).	
		Length.	Breadth at middle.			Length.	Breadth at middle.
Fruit.....	10	63.5	4.6	Twig of current year ¹	10	48.5	4.7
Do.....	10	65.0	4.2	Leaf.....	10	57.9	4.6
Do.....	10	73.0	4.2	Do.....	10	60.8	4.6
Overwintered twig.	20	42.1	5.5	Do.....	10	57.0	4.5
Do.....	10	42.7	5.0				

¹ Conidiophores in early stage of sporulation; consequently, relatively short.

Conidia.—The conidia (fig. 5, *a* and *b*) are borne acrogenously, either singly or in short chains which may be branched when conditions especially favor sporulation. The spores appear first as small, rounded, hyaline projections from the apices of the conidiophores. These bodies rapidly enlarge, assume the ellipsoidal shape of the immature spore, and become abjoined by septa from their sporophores. The mature conidia are very well described by Von Thümen (1879, p. 13).

* * * sporis fusoido-ovatis, utrinque obtusiusculis vel raro vertice subacutatis, rectis, non vel obscure uniseptatis, diaphanis, 20 μ long., 5–6 μ crass., dilute fuscescentibus.

If divided, the spores tend to be slightly constricted in the middle. The cells are very similar in size and shape, except that the basal ones tend to be slightly thicker and the apical less obtuse. In nature, normal mature conidia are fairly uniform in size. When they are produced in chains, the mature apical spores are indistinguishable in size and shape from the basal. The results of the measurements of 240 conidia from various sources are summarized in Table III. These measurements agree closely with those of Von Thümen (1879) except that the spores average 4.3 μ shorter.

TABLE III.—Measurements of conidia of *Cladosporium carophilum*.

Source.	Number measured.	Average measurements (microns).		Source.	Number measured.	Average measurements (microns).	
		Length.	Breadth.			Length.	Breadth.
Fruit.....	10	16.7	5.0	Leaf lamina.....	20	16.6	4.9
Do.....	50	14.4	5.2	Do.....	20	16.2	4.7
Overwintered twig lesions.....	50	15.5	5.2	Do.....	20	15.6	4.8
Twig of current year.....	20	16.8	4.8	Do.....	20	16.5	5.1
Do.....	20	14.9	4.2	Leaf midribs.....	10	17.2	4.5
				Average of 240.....		15.7	4.9

PHYSIOLOGY.

The objects of the physiological studies were (1) to gain a clearer comprehension of the responses of the fungus to its environment under controlled conditions, in order better to understand its behavior in nature, and (2) to furnish a further basis for the identification of the organism by other investigators.

CULTURAL STUDIES.

By means of the poured-plate method the fungus was readily isolated from freshly produced conidia from fruit, twig, or leaf lesions. At first, considerable difficulty was encountered, because the scab fungus developed so slowly that it became overrun by saprophytes. It was possible, however, to minimize the contamination by

collecting the spores in a platinum loop of water touched to the ends of sporulating hyphæ. In cases where other measures were necessary, individual spores were isolated by a method which the writer (1915) has described elsewhere. By the use of this method all the cultures reported upon in this bulletin were isolated from single spores.

The organism was also isolated from leaf and twig lesions by sterilizing the surfaces with mercuric chlorid in the usual fashion and plating fragments in agar preparations. This method, however, was rendered unsatisfactory (1) by the superficial nature and slow growth of the fungus and (2) by the prevalence of a species of *Dematium* which agrees morphologically with the description of *Dematium pullulans* De By. This organism grows very rapidly in culture and forms myriads of spores, from which it is very difficult to isolate the slow-growing *Cladosporium*.

In connection with these isolations, observations were made to ascertain what organisms are commonly associated with scab lesions. Hundreds of plates were made from scrapings from scab infections on fruits, twigs, and leaves. The media most commonly used were agar in water, with prune decoction added, Lima-bean agar, and Thaxter's potato hard agar. *Cladosporium carpophilum* developed uniformly when the plates contained freshly produced normal spores, but it frequently failed to appear if the lesions had passed through adverse conditions, such as exposure to excessive heat or drought. The following organisms appeared frequently: *Dematium* sp., *Hormodendron* sp., and two undetermined imperfect fungi, hereafter designated for convenience as undetermined fungi A and B. While these four organisms appeared frequently and abundantly, only the *Dematium* developed constantly. All occurred superficially, and all were readily isolated from apparently normal surfaces of fruits, twigs, and leaves, as well as from scab lesions. The *Dematium* and the *Hormodendron* were especially abundant on dead tissues. While there was little reason to suspect that any of these superficial fungi bore a causal relationship in the production of scab, they were all isolated in single-spore cultures and tested for pathogenicity. The results, which were uniformly negative, are discussed later.

CULTURAL CHARACTERS.

Strains of the fungus isolated from (a) fruit, (b) twig, and (c) leaf lesions, respectively, were grown comparatively in triplicate cultures on 31 media. No marked differences occurred in the behavior of strains from the different organs of the host, the variations being no greater than those observed in strains isolated from the same organ. The fungus grew well on this wide range of media, and

showed only minor variations upon the different substrata. The more important features of this work are outlined as follows:

Lima-bean agar plates.—In diffuse light in the laboratory, at 18° to 25° C., the conidium puts out one or more colorless septate germ tubes, each of which in two days may attain a length of about eight to twelve times that of the spore. The cells of these hyphæ then thicken, develop numerous lateral branches, and become olivaceous. The younger hyphæ behave in like fashion. Thus small, compact colonies develop, their central areas being composed of dense, pseudoparenchymatous masses of heavy, often swollen and moniliform, thick-walled, olivaceous cells from which radiate numerous branched hyphæ. The colonies usually become macroscopic within three to five days and attain their full development within two to four weeks. When fully developed they may be irregularly spherical to lens shaped or irregular and more or less submerged, depending upon the position of the parent spore. The exposed portion of the stromateoid mass is masked by an olive-green covering of conidiophores, conidia, and rather sparse, slender, olivaceous, aerial hyphæ. The submerged parts are dense and black, except at the periphery, where the young hyphæ are colorless. While the size of the colonies varies much with conditions, the surface diameter averages about 1 to 4 mm.

Lima-bean agar slants.—The early development of the fungus parallels that on plates. The subsequent growth, however, is much more vigorous and continues for a longer period. In a culture seeded with a small droplet of sporiferous suspension on the middle of the slanted surface and incubated at 18° to 25° C. under conditions which retard rapid evaporation, the colony may eventually occupy practically the entire slant, gradual growth continuing for more than three months. At the end of four months the exposed portion consists of a black, irregularly circular, stromateoid mass about 1 to 1½ cm. in diameter, somewhat raised and slightly convoluted, masked by an olivaceous covering of conidiophores, conidia, and slender, aerial hyphæ. From this central mass heavy, branched, olivaceous to black hyphæ penetrate the slant practically to the wall of the tube.

Beerwort agar slants.—The early development closely parallels that on the Lima-bean agar, except that it is somewhat more rapid and the growth above the surface of the medium is markedly more abundant. The latter difference becomes very striking in later stages, when the much-folded and convoluted mycelial masses of the cultures on beerwort agar extend several millimeters above the original surfaces of the slants, sometimes reaching the opposite walls of the tubes. The subsurface development extends through the slants to the walls of the tubes. In the later stages the raised, stromateoid masses become studded with microsclerotia.

Other agar slants.—Strains of the fungus isolated from (a) fruit, (b) twig, and (c) leaf lesions were studied comparatively on 16 agar preparations, viz, infusions of peach fruit, peach leaf, peach twig, prune (pitted, 2 per cent and 5 per cent), Lima bean, potato, corn meal, oat meal, and string bean; standard beerwort, malt soup, synthetic, Thaxter's potato hard (3 per cent agar), beef-extract agar; and agar alone (1.5 per cent) in water. These media were prepared with the aim of securing as much uniformity as feasible in matters common to all, as periods of cooking and sterilization, percentage of agar used (1.5 per cent, unless otherwise noted), and technique of manipulations. For the standard media standard methods were followed throughout. All the media were titrated, but it was not considered desirable to readjust the reactions, previous tests having shown no noticeable effect of reaction in a range more extensive than that occurring in these cultures. The cultures were made in triplicate, incubated in darkness at 20° to 22° C., and examined frequently during their development.

While the development of the fungus varied considerably with the different media, these variations did not appear to be of a nature to justify detailed descriptions. The chief differences were (1) the amount of growth above the surface of the slant, (2) the

production of microsclerotia, and (3) the depth of growth below the surface of the medium. The most conspicuous development above the surface of the substratum occurred on beerwort and synthetic agars. A greater or less development of this type and the production of abundant microsclerotia occurred on all the sugary media used. Little of the elevated stromateoid growth occurred upon starchy media, nor were microsclerotia observed in such cultures. The subsurface development on the starchy media, however, was very vigorous. On agar in water the fungus developed slowly until the colonies were about $1\frac{1}{2}$ cm. in diameter, though they were considerably less dense than on the more nutritive substrata, and their development above the surface of the slant was very limited. The variations in strains from different organs of the host were very minor, being no greater than have been observed in strains isolated from the same organ.

Prune gelatin slants.—The early development of the fungus parallels that on prune agar. The subsurface growth, however, soon becomes considerably more rapid on the gelatin cultures. While no marked liquefaction is apparent, there is some evidence of the softening of the medium immediately adjacent to the advancing hyphae. It is quite possible that liquefaction occurs very gradually, the liquefied areas being occupied by the fungus as rapidly as the medium becomes softened. The fully developed colonies occupy the entire slanted sections and extend somewhat into the medium below.

Lima-bean agar shake cultures.—The fungus develops quite vigorously and typically upon the surface of the medium, and good growth occurs to a depth of 1 to 2 mm. At greater depths colonies develop at various points throughout the culture, but they grow very sparsely and barely become visible macroscopically.

Other media.—The same strains of the fungus used for the agar slant cultures were grown comparatively, at the same time and under like conditions, upon the following media: Prune decoction (2 per cent) in (1) tubes, (2) elder pith, (3) plaster-of-Paris blocks, and (4) filter paper; peach fruit and leaf decoctions in filter paper; steamed bean pods; sweet-clover stems; peach twigs; peach leaves; potato plugs; rice; corn meal; and sterile raw potato plugs. The developments were not sufficiently distinctive to justify detailed descriptions. In the prune decoction the fungus developed abundantly at the surface of the liquid and formed fairly vigorous colonies along the walls of the tubes to the bottom. Good growth occurred on all the other media, though the development on raw potato was quite sparse while the plugs were fresh. Later, the growth was very good. The most striking feature of these cultures was the conspicuous development of microsclerotia upon the peach twigs. The differences among the strains were no more marked than in the agar slant cultures.

RELATIONS OF MOISTURE.

The cultural studies reported above showed that the fungus may grow vigorously on or in a suitable nutrient solution or saturated substratum. If the substratum was gradually dried, however, the cell walls of the fungus thickened and became olivaceous, and chlamydospores were developed in great abundance. In this condition the organism was found to be highly resistant to desiccation. This was strikingly shown in the case of Lima-bean agar slant cultures, which were made on December 8, 1911, and kept in the laboratory, where they dried gradually and became very hard and brittle. On April 15, 1915, mycelial fragments from one of these cultures were plated. Good growth and sporulation resulted.

RELATIONS OF TEMPERATURE.

Several series of cultures were incubated in darkness at carefully controlled temperatures ranging from 2° to 40° C. The media used were Lima-bean and beerwort agars and steamed string-bean pods. At 2° C. the growth was very gradual, becoming barely macroscopic in about a month. At 4° and 6° C. the development was slightly more rapid, while at 9° and 12°, respectively, it was conspicuously accelerated. The rapidity of growth increased steadily up to 20° C., while at 24° a slight increase over 20° could be observed. At 27° C. the development closely paralleled that at 24°, being, perhaps, slightly less rapid. At 30° to 32° C. the fungus rarely became macroscopic, while no growth occurred at 35°. Cultures incubated for three weeks at 35° C. developed vigorously, however, when the temperature was decreased to 24°.

It appears, therefore, that the minimal temperature for growth of the fungus on favorable substrata is less than 2° C.; the optimal, between 20° and 27°—about 25°; and the maximal, about 32°.

RELATIONS OF LIGHT.

Numerous cultures on Lima-bean and beerwort agar slants and steamed string-bean pods were incubated comparatively side by side in strong diffuse light and in darkness, at temperatures ranging from 20° to 25° C. Excellent development resulted in all cases, the cultures of the two series being practically indistinguishable, except for the fact that sporulation was uniformly distinctly more abundant in the case of those grown in light. Good sporulation, however, occurred in the cultures grown in darkness.

In certain cases, in January and February, parallel cultures were incubated for several weeks in a south window, where they were exposed to direct sunlight for several hours of each clear day. Inasmuch as no effort was made to segregate the effects of light and temperature, these experiments merely showed that cultures which had been frequently exposed to direct sunlight under these conditions appeared to suffer no permanent injury, their ultimate development being good.

It appears, therefore, that strong diffuse light exerts no marked influence on the vegetative development of the fungus, but distinctly favors sporulation.

SPORE-GERMINATION STUDIES.

More than a thousand germination tests were made with conidia from various sources under varied conditions. Only certain general aspects of the results will be considered here. Data regarding viability are given in another connection (p. 35).

The spores were placed in drops of sterile distilled water, meteoric water, and nutritive solutions, respectively, on glass slides in moist chambers; in liquid and solid media in Van Tieghem cells; and in plate cultures of agar infusions. The cultures were incubated under various regulated conditions. The glassware was cleaned in the standard manner for physiological experiments, and distilled water was redistilled from Jena glass. For most purposes, the open drop cultures on glass slides in Petri dishes were most convenient and satisfactory.

GERMINATION IN WATER.

In diffuse light or in darkness, at 18° to 27° C., the first evidences of the germination of conidia in sterile distilled water appear, after about 8 to 12 hours, as small, highly refractive, hyaline protuberances of the inner walls of the spores. These gradually develop into delicate, hyaline, septate germ tubes, 2 to 4 μ in diameter, which usually attain a length of about 10 to 20 μ within 24 hours after the beginning of the experiment. Little growth occurs after the second day, when the tubes are usually 30 to 60 μ long. They rarely become longer than 75 μ unless suitable nutritive material is added. The germ tubes may extend from any part of the surface of the spore, but ordinarily they are developed at or near the ends. If only one is produced, it is generally borne at or near the basal end. Frequently a tube is developed from each end, but rarely are more than two produced from a single spore in pure water.

In parallel experiments with sterile distilled water and meteoric water no noteworthy differences in results were observed.

GERMINATION IN NUTRIENT MEDIA.

In drops of 1 per cent prune or raisin decoction, or a variety of other similar nutrient solutions, the early development of germination is practically indistinguishable from that in water, the effects of the nutrient media being manifested chiefly in the rapidity and vigor of development. In such solutions, under the conditions already mentioned, early stages of germination may be observed within 4 to 8 hours. After 12 hours the germ tubes usually measure about 3 to 4 by 15 to 25 μ . Within two days they frequently attain a length of 150 to 250 μ and become considerably thickened, branched, and septate.

In sap expressed from green Elberta peaches germination is practically indistinguishable from that in 1 per cent prune decoction.

In plates of 1 per cent prune agar, or a variety of similar agar infusions, germination closely parallels that in drops of prune decoction.

In Van Tieghem cells the spores germinate normally in various liquid and solid media.

RELATIONS OF MOISTURE.

While no attempt was made to determine whether or not the conidia will germinate in a highly humid atmosphere in the absence of water, no evidence of this type of development was observed. On the contrary, cumulative observational data strongly indicate that at least a film of water is essential to germination. Continuous wetting, however, is unnecessary, as was shown in the following experiment:

Experiment 1.—Spores were placed in drops of sterile distilled water and 1 per cent prune decoction, respectively, on slides in moist chambers and incubated in diffuse light in the laboratory at 15° to 25° C. In one series the drops were not allowed to evaporate. In two others the spores were kept alternately wet and air dry for 24-hour periods, one series being wet during the first period and the other dry. The experiment was continued for six days and noted daily. The spores which were kept continuously moist germinated normally and at the end of the experiment showed somewhat better growth than the others. Those which were alternately wet and dry showed little if any injury from the treatment. They ceased to develop when dry, and resumed their activities when wet. At the end of the experiment these two series were indistinguishable in their development. Other similar tests in which the periods of wetting and drying were varied gave confirmatory results, no serious injury being observed unless the changes were very frequent in the earlier stages of germination.

RELATIONS OF TEMPERATURE.

Several series of germination experiments were conducted in drops of sterile distilled water and 1 per cent prune decoction, comparatively, on glass slides in moist chambers in darkness at carefully controlled temperatures ranging from 2° to 35° C. The spores were taken from vigorous Lima-bean agar cultures 2 to 4 weeks old. At 2° C. germination in sterile distilled water was practically nil, only occasional tubes, with a maximal length of about 20 μ , being observed at the end of 15 days. In the parallel cultures in prune decoction, early evidences of germination were visible after three days. Within four days numerous tubes 5 to 10 μ long were evident, while at the end of 15 days most of the spores had germinated, their tubes averaging more than 100 μ in length. At 4° and 6° C., respectively, the rate of development was slightly increased. At 9° and 12° C. it was in each case materially accelerated, and up to 20° it increased steadily. The cultures at 24° C. were slightly more advanced than at 20° and almost indistinguishable from those at 27°, though apparently very slightly more vigorous. At 30° to 32° C. the spores germinated but sparsely. The tubes in the prune decoction rarely exceeded 60 μ in length and failed to develop into mycelia or to produce spores. At 35° C. no germination was observed.

It appears, therefore, that the thermal relations of germination closely parallel those of subsequent growth, the minimal temperature for germination in water or in favorable nutritive solutions

being less than 2° C.; the optimal, between 20° and 27°—about 25°; and the maximal, slightly above 32°.

RELATIONS OF LIGHT.

Numerous drop cultures of the type just mentioned were incubated comparatively in strong diffuse light and in darkness at temperatures ranging from 20° to 25° C. Normal development resulted in all cases, the differences in illumination appearing to have no marked influence on germination.

PATHOGENICITY.

Relative to an inoculation experiment with *Cladosporium carpophilum* from culture, Chester (1897, p. 63) makes the following statement:

Sown on the uninjured surface of green peaches, a slight growth resulted, in only a few cases simulating the natural infection; it was evident, however, that the peaches were at that stage of their development not in condition for the best development of the fungus on their surface. When the inoculation of the peach was accompanied by a puncture, the fungus developed and produced spots like those seen in nature.

Thus, no definite data are given concerning the source of inoculation, the method of experiment, or the results obtained, and no mention is made of controls. Furthermore, the writer's experiments, reported below, show that punctures are not essential to abundant infection, and that the utmost care is necessary for the attainment of reliable results from fruit inoculation with *Cladosporium carpophilum* in sections where scab occurs abundantly. This experiment, therefore, does not justify conclusions.

Aderhold (1901, p. 657) conducted a cross-inoculation experiment with *Cladosporium cerasi* and *C. carpophilum*. The results, however, were admittedly inconclusive.

The writer (1914a, 1914b) reported, in a preliminary way, positive results from inoculating peach fruits, twigs, and leaves with *Cladosporium carpophilum* from various sources. The results of these and further experiments are given more completely below. They comprise, so far as the writer has been able to ascertain, the only authentic records of positive results from inoculation experiments with this fungus.

FRUIT INOCULATIONS.

Preliminary experiments and observations of two seasons showed clearly that under field conditions where the disease occurs abundantly, successful fruit inoculations with peach scab must be planned to overcome the following difficulties: (1) The abundance of natural infection, rendered especially baffling by the long period of incubation of the fungus, and (2) the difficulty of obtaining at will condi-

tions suitable for infection. These conditions led to the development of a special technique, of which the following is a brief outline:

In order to overcome the first of these difficulties the fruits used for the inoculations were bagged as soon as practicable after the shedding of the calyces, and were kept protected in this manner throughout the course of the experiments; the number of controls was made as large as circumstances permitted; and the inoculations were made in numerous corroborative series upon areas least subject to natural infection, about one-half of the total number being made upon the protected equatorial surfaces, which are normally free from natural infection, even under the most severe conditions (Pl. III, fig. 1).

The bags used were made to order from a thin, translucent, partially waterproofed (glassine) paper. They were 11 inches wide and 14 inches long, but 12 by 16 inches proved later to be a more convenient size.

In order to secure at will favorable conditions for infection it became necessary to devise a method for the satisfactory regulation of moisture. In continuation of preliminary experiments made in 1912 a very simple and satisfactory contrivance was developed. It was even better adapted to twig than to fruit inoculations and should be capable of general adaptation in inoculation work of this type, where moisture is a limiting factor and where it is impracticable to conduct the experiments in moist compartments. The apparatus, which works by capillarity, is readily understood by reference to figure 6. One end of a wick of wet absorbent cotton (*A*) is appressed to the area to be moistened, while the other end

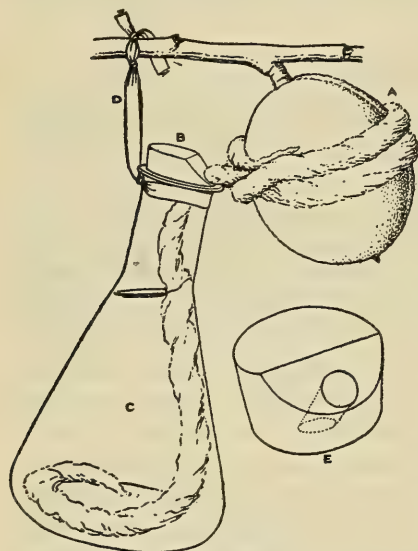


FIG. 6.—Device for supplying moisture for outdoor inoculations: *A*, Wick of absorbent cotton; *B*, cork; *C*, water container; *D*, attachment to host; *E*, enlargement of *B*. (*A* to *D* are about one-half natural size.)

extends through a small orifice in a cork (*B*) into a water container (*C*), which is attached by means of a soft tape (*D*) to some convenient part of the host. The size and shape of the container may be adapted to suit the convenience of the operator. Lipped test tubes, 18 by 150 mm., were used in the earlier experiments, because they were the only suitable apparatus available at the time. They were quite satisfactory, but small, light, lipped flasks later proved more desirable, as they are more capacious and render the device more compact.

With the apparatus used it was found practicable to keep twig inoculations thoroughly moistened for two weeks without refilling, while a moist zone three-fourths of an inch wide could be maintained about a peach $1\frac{1}{2}$ inches in diameter for four days. The container is refilled easily by removing the cork, without disturbing the arrangement of the upper portion of the wick. For convenience of attachment it is distinctly advantageous to allow the wick to enter the container from one side of the cork rather than from the center, while corks cut as shown in figure 6 (*E*) are easily manipulated and are unlikely to abrade the adjacent tissues of the fruit. If the wick fits loosely in the orifice or if the cork is lightly inserted in the flask, no strain is exerted upon the fruit by the swaying of the water container by the wind. Any such lateral motion is readily taken up by the short section of the wick which extends

from the mouth of the flask to the surface of the fruit. In many cases fruits can be found so situated that the neck of the flask may be firmly attached to the twig and swaying rendered impossible.

METHOD OF INOCULATION.

The method employed in the fruit-inoculation experiments of 1913, in all essentials applicable to all the fruit-inoculation work, is briefly described as follows:

All inoculation work of the season of 1913 was conducted in the orchard of Mr. I. C. Wade, Cornelia, Ga. The trees used were 8-year-old Elbertas, located on a sandy clay soil, with good air and surface drainage and a western exposure. On account of the freeze of March 29 the crop was very short. This part of the orchard was, consequently, unsprayed.

The experimental fruits were carefully selected and bagged on May 8, about three weeks after the falling of the calyces. The bags were of heavy manila paper, but they were replaced after a few days by the glassine bags, which had been delayed in shipment. The bagging was planned for an earlier date, but was delayed, pending the arrival of the glassine bags, as long as outdoor conditions seemed to render protection from natural infection unnecessary. The three weeks preceding May 8 were unusually favorable in this respect, comprising a period of unbroken drought except for a very slight shower on April 26 and another on April 27, both of which were followed by brisk winds which rapidly dried the trees. Furthermore, microscopic examinations of scab lesions on twigs from the field showed practically no production of conidia during this period. Thus any considerable natural infection of the experimental fruits prior to bagging was not considered feasible. The correctness of this assumption was clearly demonstrated in the course of the experiments, as will be set forth later.

The inoculations were made on noted oval areas about 3 cm. horizontally by 2 cm. vertically on the exposed and on the protected equatorial surfaces of the fruits. The spores were applied in suspension in sterile water or in nutrient solutions by means of sterile De Vilbiss atomizers. The surfaces inoculated, being highly resistant to wetting, were gently tapped with a finger, in order to facilitate the penetration of the spore-bearing liquid through the thatch of hairs to the epidermal cells. The hands were washed and rinsed in sterile distilled water prior to the application of each sporiferous suspension, and due precautions were, of course, observed throughout the operations to prevent mixing the sources of inoculation. As soon as each inoculation was made, a moisture apparatus of the type previously described was attached in such fashion as to maintain a moist zone approximately 2 cm. wide about the equatorial region of the peach. The bag was then replaced.

All apparatus used was thoroughly clean, and all glassware and metal ware was sterilized.

The watering apparatus, which functioned for about four days after filling, was refilled at noted intervals, which varied with the different series.

Throughout the season the inoculations were noted at intervals of about one week.

In certain cases bags were torn. The facts were noted and new bags were put on. There was no evidence of the entrance of infection in any such case. In the light of life-history studies outlined later, this is not surprising, since the rents always occurred in such position that an unbroken thatch covered the fruit and prevented access of water-borne spores.

All inoculations were made in triplicate unless otherwise noted, and germination tests were made with drops of each sporiferous suspension used.

REPORT OF A TYPICAL EXPERIMENT.

As illustrative of the fruit-inoculation experiments, one typical series planned for securing final evidence regarding the pathogenicity

to peach fruits of the organisms concerned is reported in some detail, as follows:

Sources of inoculation.—The sources of inoculation were 11-day-old Lima-bean agar cultures of single-spore strains of *Cladosporium carpophilum*, undetermined fungus *A*, undetermined fungus *B*, and *Dematium* sp., all of which had been isolated from peach twigs. Sporiferous suspensions were obtained by introducing a few cubic centimeters of sterile distilled water into each culture tube, scraping the surface of the fungal growth lightly with a sterile platinum needle, and shaking.

Germination tests were made on sterile glass slides in moist chambers with drops of the sporiferous suspensions used for the inoculations. The results are shown in Table IV.

TABLE IV.—*Summary of a germination test of the spores used in a typical fruit-inoculation experiment, Cornelia, Ga., 1913.*

Organism.	Estimated germination in 3 days (per cent).	
	Sterile distilled water.	Prune decoction.
<i>Cladosporium carpophilum</i>	80	99
Undetermined fungus <i>A</i>	99	99
Undetermined fungus <i>B</i>	90	90
<i>Dematium</i> sp. (budding).....	99	99

Methods.—On June 6, fruits bagged on May 8 were inoculated, the technique above described being followed in every respect except that in one-half of the series 0.09 per cent prune decoction was substituted for distilled water in the sporiferous suspensions and in the moisture apparatus. The moisture devices were refilled with sterile distilled water on June 11, June 20, July 17, and July 23.

Results.—The detailed results of these inoculations are summarized in Table V.

On the 16 control areas, Nos. 421 to 424 and 437 to 440, not a single infection occurred. The results of Nos. 425 to 427, inoculated with *Cladosporium carpophilum*, are particularly striking and confirm beyond question those of preceding parallel experiments. On the six inoculated areas 406 infections developed, while on the uninoculated areas of the three fruits only one infection occurred. The results from the six similar inoculations, Nos. 441 to 443, in which prune decoction was substituted for distilled water, furnish still further confirmation of those of the preceding experiments, 127 infections occurring upon the areas inoculated. Only in the case of No. 441 did any infection appear upon uninoculated surfaces of these fruits, 12 lesions developing within a few millimeters of the peduncle. This case stands alone among the fruits bagged on May 8 and apparently represents an unusual instance of early infection about the peduncle prior to bagging. This infection, however, should not be allowed to lessen confidence in the results of the inoculation. That the infections upon the inoculated areas resulted from the inoculation and not from natural infection is conclusive, because (1) on 100 control areas in this and the three other series of similar experiments not one infection occurred; (2) the disease appeared upon the inoculated areas at the same time that it became evident upon each of the other similarly inoculated areas of this series; (3) the lesions about the peduncle were separated from those upon the areas of inoculation by a zone of clean surface three-fourths of an inch wide; and (4) in no case has natural infection been observed to occur abundantly about the stem cavity, over the equatorial wettable surface, and over the equatorial protected surface

of one fruit, even under the most severe conditions of natural infection (Pl. III, fig. 1). Nos. 428 to 436 and 444 to 452, inoculated with *Dematium* sp. and with the undetermined fungi *A* and *B*, developing no disease upon the areas of inoculation, confirm the negative results of preceding parallel experiments and may be considered as supplementary controls.

In this series, including 32 fruits, 15 scattered infections, which have not been discussed, occurred upon uninoculated areas. These evidently resulted from occasional chance infections, which obviously can not be entirely precluded in work of this type. Their number, however, is so small in comparison with the number of infections resulting from inoculations that they are clearly negligible. Furthermore, the areas of inoculation were so chosen with reference to the parts of the fruit subject to natural infection that even this minimal amount of chance infection appears to have been escaped, as is witnessed by the freedom from disease of all the 100 control areas.

TABLE V.—Summarized results from a typical fruit-inoculation experiment, Cornelia, Ga., 1913.

Inoculation.		Number of infections after stated number of days (28, 42, 52, or 60) had elapsed.																												
		On inoculated areas.									On uninoculated areas.												Total infections.							
Source and medium.	Serial No.	Wettable surface.			Protected surface.			Wettable surface.						Protected surface.						On inoculated areas.			On uninoculated areas.							
								Above inoculated area.			Below inoculated area.																			
		28	42	52	60	28	42	52	60	28	42	52	60	28	42	52	60	28	42	52	60	28	42	52	60	28	42	52	60	
Distilled water:																														
Control.....	421	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Do.....	422	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	1	0	0	0	0	0	0	0	0	0	1	2	
Do.....	423	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Do.....	424	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	1	---	
C. carpophilum.....	425	0	5	45	63	0	0	55	128	0	0	0	0	0	0	0	0	0	0	0	5	10	191	0	0	0	0	0	0	0
Do.....	426	0	6	41	48	0	6	24	35	0	0	0	0	0	0	0	0	0	0	0	12	65	83	0	0	0	0	0	0	0
Do.....	427	0	8	42	66	0	10	61	70	0	0	0	1	0	0	0	0	0	0	0	18	103	136	0	0	0	0	0	0	1
Undetermined fungus A.....	428	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	a1
Do.....	429	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	(b)
Do.....	430	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	a0
Dematium sp.....	431	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	a0
Do.....	432	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	a0
Do.....	433	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	(b)
Undetermined fungus B.....	434	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	(b)
Do.....	435	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	a0
Do.....	436	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	(b)
Prune decoction (0.09 per cent):																														
Control.....	437	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Do.....	438	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Do.....	439	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	---	
Do.....	440	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
C. carpophilum.....	441	0	0	20	23	0	25	35	0	0	12	0	0	0	0	0	0	0	0	0	0	45	58	0	0	0	0	0	0	c12
Do.....	442	0	0	4	4	0	0	10	15	0	0	0	0	0	0	0	0	0	0	0	14	19	0	0	0	0	0	0	0	0
Do.....	443	0	0	8	8	0	0	24	42	0	0	0	0	0	0	0	0	0	0	0	0	32	50	0	0	0	0	0	0	0
Undetermined fungus A.....	444	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	(d)
Do.....	445	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	(b)	
Do.....	446	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	(b)
Dematium sp.....	447	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	a0
Do.....	448	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	2	(b)	
Do.....	449	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	(b)
Undetermined fungus B.....	450	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	(d)
Do.....	451	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	(d)
Do.....	452	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	(b)

a Considered as supplementary controls.

b Considered as supplementary controls; no records were made for these fruits on these days.

c See discussion of results on p. 24.

d Fruit shed before results were conclusive.

SUMMARIZED REPORT OF ELBERTA INOCULATIONS.

A brief summarized report of the Elberta fruit inoculations is given below (Pl. V, figs. 1 to 5).

Sources of inoculation.—*Cladosporium carpophilum* from cultures and directly from abundantly sporulating lesions on peach twigs, and undetermined fungus *A*, undetermined fungus *B*, and *Dematium* sp. from cultures. Only young, vigorously sporulating Lima-bean agar slant cultures of single-spore strains isolated from peach twigs were used.

Methods.—Fruits bagged on May 8 were inoculated by the methods previously described in four series on May 16, May 20, May 27, and June 6, respectively, and the inoculated areas kept intermittently moist until maturity.

Results.—In a few cases the experimental fruits were shed or were lost by accidental mechanical injury, while in a few of the earlier direct inoculations the spores used failed to germinate. These inoculations are not included in this summary.

On 16 areas inoculated with undetermined fungus *A*, 16 with undetermined fungus *B*, and 16 with *Dematium* sp. no infection resulted. Consequently, these inoculations may be considered as supplementary controls.

On the 100 control areas of the four series, including as controls the 48 inoculations with the superficial fungi mentioned in the preceding paragraph, not one scab infection developed. Upon the entire protected surfaces of the 50 fruits in question only one lesion appeared, this being in all probability the result of a chance infection subsequent to the time of inoculation. Upon these 50 fruits the total number of infections was only 21, while 35 matured without showing any evidence of the disease.

On the 18 areas inoculated with *Cladosporium carpophilum* from pure cultures, 707 typical infections appeared, an average of 39 lesions on each inoculated area. Only one of the 18 inoculations failed to result in definite and satisfactory infection, this being undoubtedly due to some local imperfection in the conditions of the experiment. In only two cases did the disease develop on uninoculated areas, sparse infection occurring in both instances near the peduncles, well away from the inoculated surfaces.

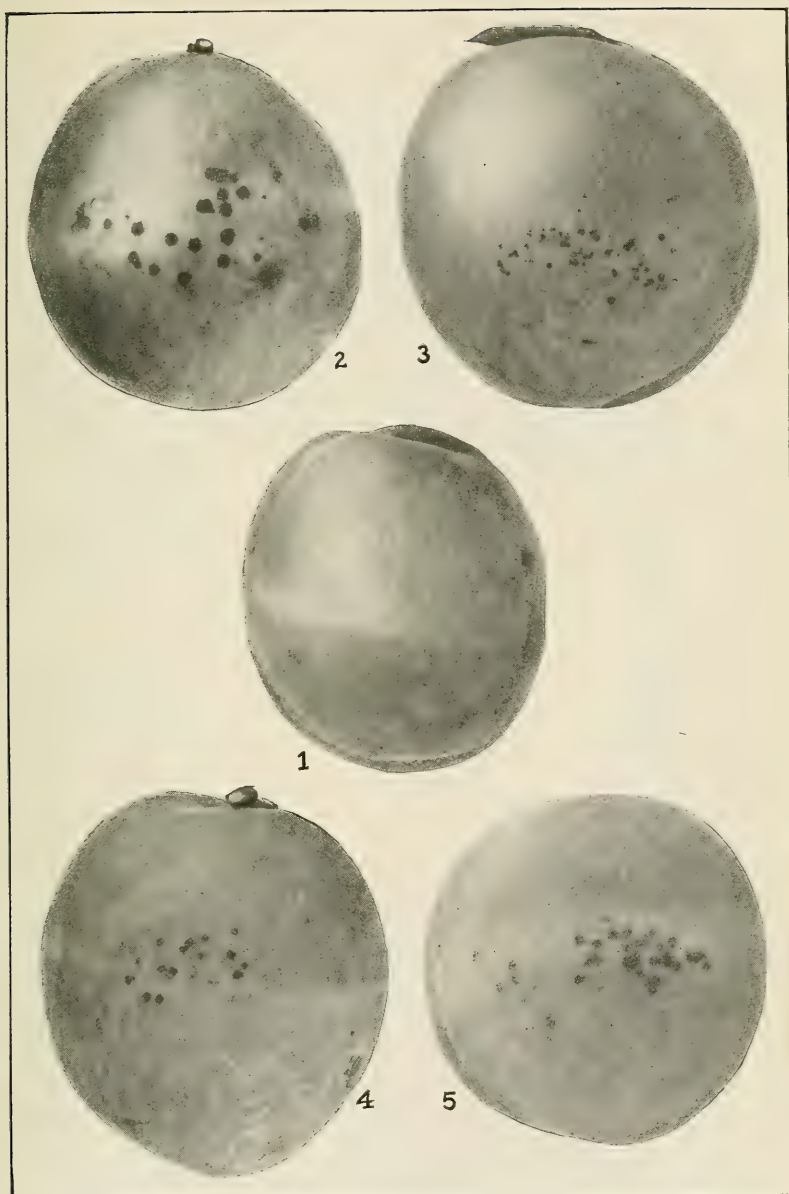
On the six areas directly inoculated with *Cladosporium carpophilum* from twig lesions, 63 typical lesions developed, every inoculation producing decisive infection. Only one lesion appeared upon the uninoculated areas of the four peaches in question. As these inoculations were made in two corroborative series and as four of them were situated upon the protected equatorial surfaces of the fruits, they were doubly guarded against natural infection and thoroughly justify positive conclusions.

CONFIRMATORY EXPERIMENTS OF 1914.

Experiments conducted at Madison, Wis., in 1914 were planned (1) to confirm the results of the preceding season in a locality where peach scab has not been observed to occur naturally and (2) to determine whether infection may occur during the early stages of development of the fruit. The report of these experiments is summarized as follows:

Sources of inoculation.—Abundantly sporulating young Lima-bean agar cultures of single-spore strains of *Cladosporium carpophilum* isolated from scab lesions of (a) fruit, (b) twig, and (c) leaf of the peach.

Methods.—On May 29, about a week after the shedding of the calyces, young Carman fruits about 8 mm. in diameter were inoculated, the methods of the Elberta inoculations of the preceding season being used throughout. The areas of inoculation and control were kept intermittently moist until June 23, when the bags and the moisture apparatus were removed and the fruits left free. Four fruits were inoculated from



ELBERTA PEACHES FROM INOCULATION EXPERIMENTS WITH *CLADOSPORIUM CARPOPHILUM*, CORNELIA, GA., 1913.

FIG. 1.—Control, no infection. Photographed August 4, 76 days after the beginning of the experiment. (Reduced, $\times \frac{4}{5}$.) FIGS. 2, 3, 4, and 5.—Inoculated with sporiferous suspensions from twig strains on noted areas of equatorial surfaces: 2, Inoculated May 20 and photographed 76 days later; 3 and 4, inoculated June 6 and photographed 59 days later; 5, inoculated May 27 and photographed 69 days later. All abundantly infected on inoculated areas. Photographed August 4. (Reduced, $\times \frac{4}{5}$.)



PEACH LEAVES AND TWIGS FROM INOCULATION EXPERIMENTS WITH CLADOSPORIUM CARPOPHILUM, MADISON, WIS., 1914.

FIG. 1.—Lower surfaces of Chili leaves: *a*, Control, no infection; *b*, inoculated by spraying with sporiferous suspension from fruit strain, badly diseased. Photographed 51 days after inoculation. (Magnified, $\times 1\frac{1}{2}$.) FIG. 2.—Lower surface of Chili leaf 93 days after spraying with sporiferous suspension from fruit strain, showing sparse primary infection and abundant secondary infection in early macroscopic stages. (Natural size.) FIG. 3.—Elberta twigs: *a*, Control, no infection; *b*, inoculated by spraying with sporiferous suspension from twig strain. Photographed 62 days after inoculation. (Magnified, $\times 1\frac{3}{4}$.) FIG. 4.—Diseased Chili twig 128 days after spraying with sporiferous suspension from fruit strain, showing abundant primary and secondary infection. (Reduced, $\times \frac{4}{5}$.) FIG. 5.—Chili twig from control paralleling the inoculation shown in figure 4; no infection. Photographed 128 days after the beginning of the experiment. (Reduced, $\times \frac{4}{5}$.)

each source of infection, while six, similarly treated but not inoculated served as controls. On June 6 this experiment was duplicated.

Results from series inoculated on May 29.—Two fruits inoculated with the fruit strain of *Cladosporium carpophilum*, two inoculated with the twig strain, and one control fell prematurely. On Sunday, August 2, before final results were available, the remaining fruits of this and the succeeding series, in spite of notices and experimental labels, fell victims to the gastronomic proclivities of trespassers. The earlier results, however, were sufficient to be of material value.

On one of the fruits inoculated with the twig strain of the fungus, eight scab lesions were barely visible on August 1, though no macroscopic infection could be observed on July 25.

On one of the fruits inoculated with the fruit strain, very early macroscopic stages of infection were observed on July 25, while 16 definite lesions were evident on August 1.

The remaining inoculated areas bore no definite macroscopic lesions on August 1, though their appearance strongly suggested the presence of abundant infection in incipient stages.

No evidence of the disease was observed upon any controls or uninoculated fruits, lesions appearing only on inoculated areas.

Results from series inoculated on June 6.—On July 25 no infection was evident. On August 1 scab lesions were discernible on one of the fruits inoculated with the twig strain of the fungus, while the appearance of the inoculated areas generally suggested the presence of incipient infection. The controls showed no evidence of infection.

REISOLATION OF THE FUNGUS.

Thorough microscopic examinations showed that *Cladosporium carpophilum* was uniformly associated with the lesions induced by inoculation. The fungus was reisolated by the poured-plate method and found to possess the typical morphological and cultural characters of *C. carpophilum*.

CONCLUSIONS.

These experiments show (1) that *Cladosporium carpophilum* from pure cultures of single-spore strains isolated from scab lesions on peach twigs or fruit is capable of causing typical and abundant infection upon peach fruit; (2) that, in like manner, this fungus taken directly from twig lesions is capable of producing the disease upon the fruit; (3) that the period of incubation of the fungus upon the fruit may vary from 42 to 77 days, very early macroscopic evidences of the disease sometimes appearing within a slightly shorter period; (4) that the presence of the nutritive solution used apparently hindered infection; and (5) that, under the conditions of these experiments, the three superficial fungi tested are not pathogenic to peach fruit.

TWIG AND LEAF INOCULATIONS.

Preliminary experiments made in 1913 showed clearly that under field conditions where the disease is prevalent, the chief difficulties attending twig and leaf as well as fruit inoculations are (1) the abundance of natural infection and (2) the difficulty of securing at will conditions favorable for infection. These obstacles were satisfac-

torily overcome (1) by conducting the experiments upon clean young trees and nursery stock in a section (Madison, Wis.) in which peach scab has not been observed to occur naturally, and (2) by using potted trees which could be placed at will under controlled conditions and by constructing moist compartments about young trees in the field.

METHOD OF INOCULATION.

The inoculations, unless otherwise stated, were made upon potted 1-year-old nursery trees which had been cut back to whips, from which vigorous young branches developed in the normal fashion in the spring. The sources of inoculation were 10-day-old to 20-day-old Lima-bean agar cultures of single-spore strains of *Cladosporium carpophilum* isolated, respectively, from the fruit, twigs, and leaves of the peach. In each experiment, parallel germination tests demonstrated the viability of the spores used. The sporiferous suspensions were prepared with sterile distilled water, as in the case of the fruit inoculations, and were applied either as spray by means of sterile De Vilbiss atomizers or by means of clean new camel's-hair brushes. Each series was adequately controlled by plants treated in every way like those inoculated except that sterile distilled water was substituted for the sporiferous suspensions. Just after inoculation the experimental plants were placed in a practically saturated atmosphere in a specially constructed moist compartment in the greenhouse, and 2 to 10 days later they were transferred to the pathological garden, where the pots were sunk to the level of the soil. In order to obtain data regarding the spread of the disease in the field, the plants were arranged in line, according to the sequence of their experimental numbers, being placed far enough apart to avoid contact. They were carefully cultivated and noted at frequent intervals throughout the season. The results are briefly outlined below (Pl. VI, figs. 1 to 5).

EXPERIMENT 1, MAY 22, 1914.¹

Sources of inoculation.—*Cladosporium carpophilum*: (a) Fruit strain, (b) twig strain; both from 13-day-old cultures.

Methods.—This experiment was conducted in the pathological garden on 3-year-old Elberta trees, numbered 851 to 854, which had been cut back to whips and had put out numerous vigorous shoots, averaging about 6 inches in length. The inoculations, except No. 854, were made by spray. The treatments were: No. 851, control; No. 852, twig strain; No. 853, fruit strain; No. 854, twig strain. On three branches of No. 854 only the upper surfaces of the leaves were inoculated, and on three others only the lower surfaces, the sporiferous suspension being applied with a clean new camel's-hair brush. The twigs bearing these leaves were also inoculated. Each experimental tree was covered by a large bell jar or a specially constructed glass box. These devices were lined with wet filter paper and blocked up on temporary platforms. In each of these moist compartments a jar of water maintained a high humidity. On the afternoons of May 23 and May 24 the trees were sprayed lightly with sterile

¹ For further details of each experiment, see the methods of inoculation previously described.

distilled water, care being taken to allow no dripping. On May 29 the glass contrivances were removed.

Results.—On June 20, 29 days after inoculation, abundant infections were barely macroscopic on the twigs and on the under surfaces of the leaves of Nos. 852, 853, and 854, with the exception of those leaves of No. 854 which were inoculated only upon their upper surfaces. These and the control plant, No. 851, developed no signs of infection during the entire season, the last observation being made on October 18. The progress of the disease is best followed in a typical example, as No. 854b. On the inoculated twig surface on June 20 occasional infections were barely visible. On July 1 about 20 infections less than 1 millimeter in diameter were observed. On July 10 over 30 lesions were definitely visible, their diameters varying from one-half to 2 millimeters. On July 17, 46 lesions were counted, the maximal diameter being 3 millimeters. During this period and subsequently the twig grew very rapidly, and bark formation began early. Consequently, the lesions developed but little further and gradually lost their identity as the season progressed. Normally, however, it should be remembered, peach twigs of older trees do not cork over during their first season's development, and on such wood the scab lesions may continue to enlarge during the following season. The progress of the disease on the leaves closely paralleled that on the twigs, except that the lesions were considerably more numerous, over a hundred frequently developing upon a single leaf.

EXPERIMENT 2, JUNE 6, 1914.

Sources of inoculation.—*Cladosporium carpophilum*: (a) Fruit strain, (b) twig strain, (c) leaf strain; all from 20-day-old cultures.

Methods.—Three potted 1-year-old Elberta trees of the type previously described were thoroughly sprayed, respectively, with the three sporiferous suspensions. Two others were inoculated with the fruit strain upon (a) the upper and (b) the lower leaf surfaces, respectively, the sporiferous suspension being applied by means of a camel's-hair brush. Two controls were sprayed with sterile distilled water. The experiment was duplicated on Chili trees of the same type. Immediately after treatment the trees were placed in the moist compartment in the greenhouse. After three days they were sprayed lightly with sterile distilled water, and five days later they were removed to the field.

Results.—On the twigs and on the lower surfaces of the leaves of the trees sprayed with the fruit and twig strains of the fungus, abundant infection was noted on July 10, 34 days after inoculation. The infections had probably been visible for several days. The lesions increased rapidly in number throughout July. The twig lesions developed slowly throughout the season, attaining a maximal diameter of 6 mm. by October 18. In September and October scattered secondary infections appeared upon the younger wood. The leaf infections typically developed as mere superficial flecks, averaging 1 to 2 mm. in diameter. In many cases, however, the leaf lamina above these flecks became yellowed, and the most severely affected leaves fell in August and September. In September and October scattered secondary infections developed, both on old leaves and on foliage which was produced after the inoculations were made.

On the trees inoculated with the leaf strain of the fungus no disease was observed until July 24, when occasional lesions were noted on the twigs and on the lower surfaces of the leaves. Little further evidence of disease developed until the latter part of the season, when a limited amount of secondary infection of the type above described appeared. The sparseness of infection from this source is attributed to the fact that this strain of the fungus sporulates much less vigorously than the others used. The spores in the suspension with which these inoculations were made were observed to be relatively sparse and to germinate with less than normal vigor. Since these characteristics are not common to all strains of *Cladosporium carpophilum* isolated from peach leaves, it is unfortunate that only this strain was available for these experi-

ments. However, the pathogenicity of other leaf strains was clearly proved in subsequent experiments.

On the leaves inoculated only on their upper surfaces no primary infection developed, with the exception of four lesions which appeared, closely grouped, at the margin of one leaf. This infection clearly occurred on the lower surface, and was probably due to chance inoculation, such as might occur should a drop of the sporiferous suspension accumulate at the margin of the leaf and extend over the edge. While great care was taken to avoid mischance of this kind, as is attested by the fact that only one other such case was observed throughout the season's work, it is obviously impracticable to secure uniformly perfect results from extensive series of experiments of this type. In September and October occasional secondary infections appeared upon the under surfaces of the leaves of these plants.

Abundant disease developed on the lower surfaces of the leaves which were inoculated on these surfaces only. Its development paralleled that on the corresponding sprayed plants.

On the four controls no disease developed, with the exception of occasional late secondary infections upon the leaves and young wood of the plant which was placed about a foot from one of the most severely infected trees of the series. This infection did not become evident until October. The fact that the next control plant, about a foot farther from the source of infection, developed no disease is of significance in relation to methods of spore dissemination, which will be discussed later.

EXPERIMENT 3, JUNE 22, 1914.

Source of inoculation.—*Cladosporium carpophilum*: Twig strain, from a 14-day-old culture.

Methods.—The inoculations were made upon potted Chili trees of the type previously described. Only the upper surfaces of the leaves of one tree were inoculated by spray, while only the lower surfaces of the leaves of another were similarly treated. A third plant was sprayed with sterile distilled water as a control. The subsequent treatment of the experimental plants paralleled that of the preceding series.

Results.—The leaves inoculated upon their upper surfaces developed no infection, with the exception of several closely aggregated lesions on the lower surface near the margin of one leaf. This infection clearly occurred upon the lower surface and was doubtless of similar origin to the parallel case discussed under experiment 2. On the leaves inoculated upon their lower surfaces, abundant infection was noted on July 17, 25 days after inoculation. The lesions had probably been visible several days. On July 24 the lesions had increased materially in number and size, scores of infections frequently occurring on individual leaves. By the end of September most of the worst affected leaves had fallen. No infection had become visible upon the control plant when it was last examined on October 18.

EXPERIMENT 4, JULY 2, 1914.

Sources of inoculation.—*Cladosporium carpophilum*: (a) Twig strain, (b) leaf strain; both from 10-day-old cultures.

Methods.—These inoculations were made upon potted Chili trees of the type used in the preceding experiment. One tree was inoculated only upon the upper leaf surfaces with the twig strain of the fungus, another was similarly treated only upon the lower leaf surfaces, and a third on both surfaces of the leaves. Very young and mature leaves were separately marked and noted. Another plant was inoculated with spray from the leaf strain of the organism, while two others were sprayed with sterile distilled water as controls. The experimental plants were subsequently accorded treatment similar to that of the preceding series.

Results.—When the last notes were made on October 18, no infection had become visible upon the leaves inoculated only upon their upper surfaces. Those inoculated upon the lower surfaces or upon both surfaces developed abundant infection of the

usual type, always on the lower surfaces. No marked difference was observed in the results from inoculations upon the very young and the mature leaves. Sparse infection developed upon the leaves of the tree inoculated with the leaf strain of the fungus, though none was found upon the twigs. No disease developed upon the controls.

EXPERIMENT 5, JULY 11, 1914.

Sources of inoculation.—*Cladosporium carpophilum*: (a) Fruit strain (isolated from an overwintered scabbed peach at Madison, Wis., May 11, 1914); (b) twig strain; (c) leaf strain; all from 17-day-old cultures.

Methods.—The experimental trees were potted Chili. One was inoculated by spray with the fruit strain and one with the twig strain, while two were similarly treated with the leaf strain. Three other plants were inoculated upon marked areas with the twig strain, one upon the upper surfaces, one upon the lower surfaces, and one upon both surfaces of the leaves. The areas to be inoculated were surrounded by circles of india ink, and the sporiferous suspension was applied in small drops by means of a camel's-hair brush. The ink was allowed to dry before the inoculations were made. Two plants were sprayed with sterile distilled water as controls.

Results.—On the trees inoculated by spray with the fruit, twig, and leaf strains, the disease developed typically and abundantly upon the lower surfaces of the leaves and rather sparsely upon the twigs. The leaf strain occasioned slightly less infection than the others, but materially more than in similar preceding tests. This increase was probably due to the fact that special care was taken to have an abundance of spores in the suspension used for this inoculation. On September 29 the tree inoculated only upon the upper surfaces of the leaves showed no infection. On the tree inoculated only upon the lower leaf surfaces, 14 of 29 inoculated areas showed infection. On the remaining inoculated plant, 66 of 98 inoculated areas on the lower surfaces of the leaves showed infection, while no disease was evident upon 93 similarly treated areas upon the upper surfaces. No infection was observed except on inoculated areas. The control plant developed no evidence of infection.

REISOLATION OF THE FUNGUS.

Numerous microscopic examinations showed that *Cladosporium carpophilum* was uniformly associated with the lesions produced by inoculation. The fungus was reisolated from twig and leaf infections induced by the fruit, twig, and leaf strains, respectively. The morphological and cultural characters of the reisolated strains were typical of *C. carpophilum*.

CONCLUSIONS.

These experiments show (1) that *Cladosporium carpophilum* from cultures of single-spore strains isolated from scab lesions on (a) fruit, (b) twigs, or (c) leaves of the peach is capable of producing abundant typical infection upon peach twigs and leaves; (2) that natural infection of the leaves occurs chiefly, and apparently exclusively, upon the lower (dorsal) surfaces; (3) that young or mature leaves may be abundantly infected; (4) that the period of incubation for leaf infection may vary from 25 to 45 days, and probably more, depending upon conditions; (5) that the period of incubation for twig infection approximates that for leaf infection; and (6) that under favorable conditions secondary twig and leaf infections may appear in the latter part of the summer.

LIFE HISTORY OF THE CAUSAL ORGANISM IN RELATION TO PATHOGENESIS.

In order to trace clearly the detailed life history of the parasite in relation to pathogenesis, it is necessary first to follow carefully the seasonal development of the disease under field conditions. This will now be briefly outlined.

SEASONAL DEVELOPMENT OF THE DISEASE.

ON FRUIT.

The first fruit infections of the season usually become evident shortly prior to the ripening period of such early varieties as the Carman. The early varieties usually show the first general infection, while the late-maturing fruits, which are usually subject to severe attacks of scab, frequently show little macroscopic evidence of the disease until several weeks later. This is probably due, in large measure at least, to the fact that infection is first mechanically hindered and later masked by the hairy thatch of the young peach, becoming visible on early varieties rather suddenly with the lightening of this covering as the fruit rapidly expands prior to maturity. The records upon which this statement is based are outlined as follows:

Supporting records.—At Cornelia, Ga., in 1912 and 1913, the peach trees were in full bloom during the last days of March. The Carmans were harvested during the first week of July, while the Elbertas ripened about a month later.

In 1912 the first scattered fruit infections were noted on unsprayed Carmans, Belles, and Elbertas on June 15, though the lesions had probably been visible for several days. On June 17, 19, and 25 the disease was increasingly evident, especially upon the rapidly maturing unsprayed Carmans, where it was quite conspicuous by July 4. As was emphasized in examining over 20,000 Carman fruits in taking results on spraying experiments, this early infection occurred almost exclusively about the depressions surrounding the peduncles and upon the closely adjacent wettable surfaces. On later varieties the disease became increasingly conspicuous until the maturity of the fruit, the lesions frequently becoming confluent over large patches.

In 1913 the course of the disease was somewhat modified by a severe spring drought, which occurred in April and early May. Scattered lesions were observed upon Carmans and Belles on June 14, while the first infections on Elbertas were noted on June 25. Only occasional infections were observed until July 1, when the disease was conspicuous upon unsprayed Carmans. On Elbertas little infection was evident until the middle of July, after which the disease became increasingly abundant.

ON TWIGGS.

Scattered twig lesions usually become evident at about the time the disease appears upon the fruit. Generally, however, they do not appear abundantly until late summer and fall. They pass the winter in various stages and complete their development during the second season.

Supporting records.—In Georgia, in 1912, the first scattered twig infection was noted on unsprayed Elbertas at Fort Valley on June 12. At Cornelia it was not observed until July 4, though it probably had been visible for more than a week.

Twig lesions remained quite scarce, however, throughout July, but began to appear in greater numbers during early August. On August 13 they were fairly abundant upon unsprayed trees in low places. On August 20 a dozen twigs were tagged and noted as to scab development. On September 10 numerous additional infections were evident on these twigs, while the older lesions had enlarged perceptibly.

In 1913 sparse twig infection was observed at Cornelia on July 14. In early August these lesions became much more abundant, and the subsequent development of the twig disease closely paralleled that of the preceding season.

It was planned to obtain exact data concerning the development of twig lesions during their second season by following closely the development of the disease on the twigs tagged and noted on August 20, 1912. Unfortunately, however, the experimental trees were "dehorned" before the writer returned to Georgia in 1913. Nevertheless, field observations in 1912 and 1913 showed beyond question that lesions may pass the winter in any macroscopic stage of development and continue their development during the next season. It was evident, further, that many late infections do not become visible until the following spring.

In the springs of 1912 and 1913 twig lesions occurred generally and abundantly. It was difficult to find a Summerour twig which was free from infection, while, in many instances, the lesions were so abundant as to become confluent.

ON LEAVES.

Owing to the inconspicuous nature of the leaf disease as it occurred under field conditions in Georgia and to its wide variance in appearance from previously published descriptions, the leaf lesions were not identified until 1913. Therefore, the writer has not had the most favorable opportunity of following closely their seasonal development under natural orchard conditions. Inoculation experiments have shown, however, that young or mature leaves may readily be infected and that the period of incubation on the leaf closely approximates that on the twig. It is evident, therefore, that the occurrence of the leaf disease should parallel that on the twigs. Such field observations as are available accord with this view.

Supporting records.—Leaf infections were first observed at Cornelia on August 21, 1913, though they evidently had been visible for some time. The lesions were not very abundant, but increased in number as the season progressed. In late September and October they were quite abundant, though inconspicuous, upon the under surfaces of unsprayed Summerour leaves.

On August 6, 1915, abundant infection was observed upon the lower surfaces of Elberta leaves at Chevy Chase, Md. The appearance of the lesions indicated that they had been visible for at least three or four weeks.

PRODUCTION OF CONIDIA.

Throughout the seasons of 1912 and 1913 the occurrence of conidia was closely followed by means of frequent examinations of scab lesions (a) directly from the field and (b) from moist chambers.

ON FRUIT.

Conidia are usually borne upon the fruit in the earliest macroscopic stages of infection and may be produced under favorable conditions

throughout the development of the lesions. Sporulation upon the fruit, therefore, may be very abundant, but its duration is relatively brief, especially in the case of early varieties.

Supporting records.—In Georgia in 1912 and 1913, conidia were usually found in greater or less abundance upon fruit lesions as soon as the infections became macroscopic, and under favorable conditions spore production occurred abundantly throughout the earlier stages of development of the spots. With the advent of the heat and drought of midsummer and late summer, however, sporulation upon the older lesions, especially those in which the diseased areas had been cut off from the surrounding normal tissues by cork layers, became practically or entirely nil.

ON TWIGS.

Conidia may be produced upon twig lesions, under favorable conditions, as soon as infection becomes visible. Usually they are borne only sparsely during the season in which the infection occurs. In the following spring, under favorable conditions, spores ordinarily appear in abundance upon overwintered twig lesions soon after the blossoming period of the peach. Subsequently, during moist periods throughout the spring and early summer they are borne profusely from this source. Usually, however, under the conditions of northern Georgia, sporulation from these lesions diminishes rapidly in midsummer and becomes practically nil in late summer. Spores may thus be produced in considerable abundance upon twig lesions at any time during the growing period of the host.

Supporting records.—Under field conditions, during their first season's development, twig lesions uniformly produced conidia very sparingly. In some cases spores were sparsely evident microscopically in the earliest macroscopic stages of infection; in others, the lesions produced only occasional conidiophores and conidia in the course of the summer. In practically all such cases observed, the conidiophores were produced singly, and only rarely were they abundant in the field. In moist chambers, however, spores were borne abundantly upon such lesions, though the conidiophores were not borne in tufts.

With the advent of spring, conidiophores appeared in abundant macroscopic olive-green tufts upon overwintered lesions. In 1913 these were first observed on April 1, when the trees were in full bloom. Careful microscopic examinations, however, revealed no conidia. Occasional conidia were found upon such hyphæ on April 11, while on April 15 and 18 they were observed in slightly increased numbers. On account of phenomenally dry weather, spore production was very sparse throughout the spring; but the fact that it would have been more abundant under favorable conditions was demonstrated by the abundant sporulation which occurred when twig lesions were held over night in a moist chamber. After the rains of early summer, spores were observed in abundance. In midsummer and late summer, however, they became more and more sparse on the overwintered lesions and more numerous on the current year's infections. As late as August 21 conidia were observed in fair abundance upon lesions on the old wood.

ON LEAVES.

Conidia may occur upon the leaves as soon as the infection is evident, and sporulation may continue under favorable conditions throughout the development of the lesions. Inasmuch as most

abundant leaf infection appears late in the season, conidia from leaf lesions are most plentiful in late summer and fall. In the cases observed by the writer, the aggregate sporulation from lesions on the leaf appeared to be much less than that from twig or fruit infections.

Supporting records.—From August 21, 1913, when leaf lesions were first observed in Georgia, until the end of the season, they bore spores in greater or less abundance. In the inoculation experiments at Madison, Wis., conidia were usually present when the lesions became macroscopic. The amount of sporulation and its period of duration upon the individual lesion appear to vary greatly with conditions.

VIABILITY AND LONGEVITY OF CONIDIA.

Hundreds of germination tests conducted during the seasons of 1912, 1913, and 1914 showed that freshly produced, normal conidia from fruit, twig, or leaf lesions are capable of germinating in sterile distilled water, rain water, or a large variety of nutrient solutions. The frequent paucity of germination from miscellaneously collected field material indicated, further, that under unfavorable conditions the viability of spores may diminish rather rapidly with age. This, however, seems to be of relatively little practical significance, since fresh conidia may be produced with the advent of conditions favorable for infection. The summarized results of a few typical germination tests are given in Table VI.

TABLE VI.—Summarized results of typical germination experiments with conidia of *Cladosporium carpophilum* from field material at Cornelia, Ga., in 1913 and at Madison, Wis., in 1914.¹

Serial No.	Date.	Variety.	Source of lesion.	Estimated germination in 3 days (per cent).	
				Sterile distilled water.	1 per cent prune decoction.
438.....	July 1, 1913	Belle.....	Fruit.....	50	90
492.....	July 22, 1913	Elberta.....	do.....	10	15
505.....	July 24, 1913	do.....	do.....	30	-----
507.....	July 26, 1913	do.....	do. ²	20	90
536.....	Aug. 22, 1913	Fox.....	do.....	0	0
275.....	Apr. 13, 1913	Elberta.....	Overwintered twig	80	99
374.....	June 7, 1913	Belle.....	do. ²	95	99
420.....	June 21, 1913	Elberta.....	do. ²	50	70
474.....	July 7, 1913	do.....	do. ²	10	10
494.....	July 27, 1913	do.....	do. ²	30	30
558.....	Oct. 7, 1913	Summerour.....	Current year's twig	50	95
566.....	Oct. 9, 1913	do.....	do.....	40	95
731.....	Nov. 1, 1914	Chili.....	do.....	95	99
660.....	Oct. 7, 1913	Summerour.....	Leaf lamina ²	60	95
668.....	Oct. 9, 1913	do.....	Petiole ²	40	95
670.....	Oct. 23, 1913	do.....	do.....	60	60
725.....	Oct. 9, 1913	do.....	Leaf lamina.....	95	99

¹ These germination tests were made in open drops upon clean sterile glass slides in moist chambers and incubated in diffuse light in the laboratory. Unless otherwise stated the spores were secured from fresh field material.

² Spores secured from material which had been held in moist chamber 2 to 4 days.

A longevity experiment is briefly reported below.

Experiment 1.—On April 16, 1915, abundantly sporulating 17-day-old cultures of a twig strain of the fungus on steamed bean pods were removed from the culture tubes

and placed in dry cloth-covered jelly glasses (*a*) in the laboratory, where the temperature ranged from 18° to 25° C., and (*b*) in the pathological garden in a covered, latticed compartment of the type commonly used for housing meteorological instruments. The cultures rapidly became air dry. The conditions precluded the further growth or sporulation of the fungus. Germination tests were made at intervals. The results, which are summarized in Table VII, show that in each series a considerable percentage of spores remained viable for more than three months. Had the spores been exposed to wetting, however, it must be remembered that they would have germinated with the advent of favorable conditions. Thus, it is not to be expected that conidia ordinarily retain their viability for long periods.

TABLE VII.—Summarized results of a longevity test of conidia of *Cladosporium carpophilum* from cultures, Madison, Wis., April 16 to October 25, 1915.

Serial No.	Date of test.	Place of storage of culture.	Estimated germination in 3 days (per cent).	
			Sterile distilled water.	1 per cent prune decoction.
786.....	Apr. 16, 1915.....	Laboratory.....	99	99
787.....	do.....	Garden.....	99	99
864.....	June 3, 1915.....	Laboratory.....	50	90
862.....	do.....	Garden.....	60	90
996.....	July 23, 1915.....	Laboratory.....	15	90
994.....	do.....	Garden.....	10	90
1004.....	Oct. 25, 1915.....	Laboratory.....	0	0

DISSEMINATION OF CONIDIA.

Studies planned to give insight into (1) the conditions under which conidia of *Cladosporium carpophilum* are detached from the parent fungus and (2) the more important methods by which they are disseminated are briefly outlined as follows:

EXPERIMENTAL WORK.

Experiment 1.—Colonies of the fungus were grown in tubes on steamed bean pods over a bean decoction in such position that spores which might be abstricted or abjected would fall into the liquid below and germinate. The experiment was run in quadruplicate and continued for six weeks. The colonies developed vigorously and sporulated profusely, but the decoction below remained sterile. After six weeks one of the cultures was shaken so that the liquid came in contact with the colony. Within three days the decoction was conspicuously clouded and darkened by the development from myriads of spores which had been detached.

This experiment was repeated with like results, while similar tests were made with a variety of other media. The results were uniformly confirmatory.

Experiment 2.—On April 19, 1915, severely infected peach twigs were placed in moist chambers. On April 23 a number of these twigs bearing abundantly sporulating lesions were placed (*a*) in moist chambers and (*b*) in dry chambers 1 cm. above glass slides smeared with glycerin. These slides were examined microscopically at intervals for two days. No spores were found.

Experiment 3.—Sections of lesions were placed under the low power of the microscope in such position that tufts of spores could be observed. Currents of air were passed over this material by means of an aspirator. The conidiophores in certain cases

could be seen to sway, but the spores remained in place. When a drop of water was brought in contact with the spores, however, they quickly became detached.

Experiment 4.—An abundantly sporulating culture on a section of a steamed bean pod was placed in a glass tube, 2 cm. in diameter and 30 cm. long, about 2 cm. from the distal end, in such fashion that no part of the colony touched the glass. A glass slide smeared with glycerin was placed about 1 cm. from the opening of the distal end of the tube in position to catch particles which might be blown through. For about 30 seconds a strong current of air was aspirated into the proximal end of the tube by means of a hand bellows. While no attempt was made to measure the velocity of the air current, it was strong enough to move the section of wet bean pod several millimeters. It was thought to be at least the equivalent of the strongest wind ordinarily affecting an orchard. Subsequent careful microscopic examination of the slide showed that only occasional spores were present. In most of these cases the conidiophores, rather than the spores, had been detached.

Experiment 5.—The culture used in the preceding experiment was gently sprayed with distilled water by means of an atomizer, in such fashion that only the finest particles of spray fell upon it. When a drop of water accumulated at the bottom of the pod it was examined microscopically and found to contain myriads of conidia.

Experiments 6 and 7.—Experiments 4 and 5 were repeated, with confirmatory results.

Experiment 8.—On April 23, 1915, a peach twig about 10 cm. long, similar to those used in experiment 2 and bearing more than 30 abundantly sporulating scab lesions, was clamped about the base by a cork which was inserted in a bottle of water. Thus, the twig was kept fresh and turgid, with about 7 cm. of its length exposed. In this condition it was placed out of doors in a brisk wind for two hours. A glass slide smeared with glycerin was placed 1 cm. away from the twig upon the leeward side, in position to catch spores which might be blown off. At the end of the experiment a careful microscopic examination of the slide revealed only occasional spores of *Cladosporium carpophilum*.

Experiment 9.—The twig used in the preceding experiment was placed in the aspirating apparatus employed in experiment 4, in such position that it did not touch the surface of the tube. The aspirator was operated as in experiment 4. Only occasional spores could be found upon the glycerined slide, though they were slightly more abundant than in the preceding test.

Experiment 10.—The twig used in the preceding test was sprayed in the manner described in experiment 5. The drops of water which accumulated contained myriads of conidia.

Experiment 11.—The twig used in the preceding test was allowed to dry over night in the laboratory. The next day it was put in the aspirating apparatus and treated as in experiment 9. The results were not materially different from those of experiment 9, though the number of conidia caught was very slightly increased.

Experiments 12 to 15.—Experiments 8 to 11 were repeated, with confirmatory results.

The results of these and of other similar experiments show: (1) That the dry conidia of *Cladosporium carpophilum* are not normally abscised or abjected; (2) that in a dry or humid atmosphere they remain persistently attached to the parent fungus; (3) that in contact with water they promptly become detached; (4) that even after spores have been detached by wetting the twigs they are not readily disseminated by wind after a period of drying. Thus, the evidence strongly indicates that under orchard conditions wind may be expected to play only a minor rôle in the dissemination of conidia, while

meteoric water appears to be peculiarly well adapted to the performance of this function.

OBSERVATIONAL DATA.

Careful field observations extending through several seasons yielded results which accord thoroughly with those of the preceding experiments. Examinations of large numbers of typically affected fruits, usually upon midseason and late varieties where the disease had reached its full development, showed two distinct types of infection, viz, (1) abundant infection extending from the depressions about the peduncles well over the wettable surfaces of the fruits and (2) sparse, scattered infections rather uniformly distributed over the wettable surfaces. In the former type, the lesions, numbering usually about 200 to 300, were uniformly most abundant about the attachment of the peduncles and over the proximal portions of the wettable surfaces of the fruits, frequently becoming confluent over considerable areas, but normally occurring less abundantly toward the distal portions. In the latter type the lesions usually numbered less than 50; while their position showed no relationship to the peduncles. Fruits of the former type were, almost without exception, borne in close proximity to twig lesions, in such position that spores could be washed down the twigs to the peduncles and thence over the wettable surfaces of the fruits. Those of the latter type were as uniformly borne in positions which precluded this method of dissemination. When infection is very severe, as upon badly diseased late varieties, these types have been observed to merge into each other.

In order to secure definite data, observations were made at Cornelia, Ga., on July 23, 1913, upon 50 fruits selected at random from a large number of trees in a badly diseased unsprayed Elberta orchard. Notes were made concerning the approximate number of infections, the areas upon which they occurred, the areas upon which no infection occurred, the proximity of lesions upon the subtending twigs, and the facility with which spores from the twig lesions might be transferred to the fruits by means of meteoric water. The results are summarized in Table VIII.

Certain striking relationships which can not be brought out in the table are here set forth:

Notes supplementing Table VIII.—No. 34 was borne in a horizontal position upon a short spur, with no chance of infection by means of water-borne spores from the subtending twig. About 5 cm. above the wettable surface of the fruit, however, numerous lesions occurred upon a horizontal twig. Thus, it is obvious that the abundant infection was induced by water-borne spores from this source.

Nos. 38, 37, 36, and 35 occurred, in the order here given, almost in contact (peduncles at intervals of about 10 cm.) upon a single twig which sloped at an angle of about 15°, with the distal end lower. The striking differences in infection are worthy of special emphasis. In the case of No. 38, the fruit nearest the base of the twig with no chance

of infection by water-borne spores from lesions upon the subtending twig, only about 25 uniformly scattered infections occurred. In striking contrast, the three fruits immediately adjacent, with excellent conditions for infection of this type, developed about 225 lesions each. Instead of being uniformly scattered over the wettable surfaces of the fruits, as would be expected had they resulted from wind-blown spores, these lesions were massed about the peduncles and over the proximal portions of the wettable surfaces, gradually becoming less abundant toward the apices. Again, had the infecting spores been wind blown, the infection should have been practically equally prevalent and similarly situated upon the four fruits in question.

TABLE VIII.—*Summary of observations concerning the occurrence and location of scab lesions on unsprayed Elberta fruits and twigs in relation to spore dissemination, Cornelia, Ga., July 23, 1913.*

[The observed infections were on the wettable surfaces of the fruits, while the protected surfaces were not infected.]

Fruit No.	Estimated lesions.	Distribution of lesions.	Distance from peduncle to nearest lesion on subtending twig.	Facilities for infection by water-borne spores from subtending twig.	Fruit No.	Estimated lesions.	Distribution of lesions.	Distance from peduncle to nearest lesion on subtending twig.	Facilities for infection by water-borne spores from subtending twig.
	Number.		Cm.			Number.		Cm.	
1...	250	Aggregated	0.5	Excellent	26...	25	Scattered	16	Poor.
2...	250	do.	.5	do.	27...	250	Aggregated	.5	Excellent.
3...	20	Scattered	(¹)	None	28...	10	Scattered	20	Poor.
4...	225	Aggregated	1	Excellent	29...	250	Aggregated	.5	Excellent.
5...	225	do.	.5	do.	30 ³ ...	12	Scattered	(¹)	None.
6...	250	do.	1	do.	31...	250	Aggregated	.5	Excellent.
7...	12	Scattered	(¹)	None	32...	40	Scattered	4	Poor.
8...	250	Aggregated	.5	Excellent	33...	60	do.	(¹)	None.
9...	12	Scattered	(¹)	None	34...	200	do.	(¹)	Do.
10...	250	Aggregated	.5	Excellent	35...	225	Aggregated	1	Excellent.
11...	250	do.	.5	do.	36...	225	do.	1	Do.
12 ² ...	20	Scattered	2	None	37...	225	do.	1	Do.
13...	225	Aggregated	.5	Excellent	38 ³ ...	25	Scattered	4	None.
14...	225	do.	.5	do.	39...	250	Aggregated	.25	Excellent.
15...	250	do.	.5	do.	40 ³ ...	20	Scattered	(¹)	None.
16...	20	Scattered	4	None	41 ² ...	25	do.	(¹)	Do.
17...	250	Aggregated	.5	Excellent	42...	250	Aggregated	.5	Excellent.
18...	250	do.	.5	do.	43 ² ...	10	Scattered	(¹)	None.
19...	250	do.	.5	do.	44...	100	Aggregated	1	Excellent.
20 ² ...	25	Scattered	6	None	45...	250	do.	.25	Do.
21...	25	do.	6	Poor	46 ³ ...	12	Scattered	(¹)	None.
22...	250	Aggregated	.5	Excellent	47...	250	Aggregated	1	Excellent.
23...	250	do.	.25	do.	48 ² ...	25	Scattered	(¹)	None.
24...	250	do.	1	do.	49...	225	Aggregated	.5	Excellent.
25 ² ...	12	Scattered	16	None	50...	30	Scattered	(¹)	Do.

¹ No lesion on subtending twig.

² Fruit, apex up, borne upon a short spur.

³ Fruit in favorable position for infection by water-borne spores from lesions on subtending twig, but not such lesion present.

These data show (1) that every badly diseased fruit observed developed under excellent conditions for infection by means of conidia from twig lesions; (2) that in all cases where conditions were favorable for the passage of water-borne spores from lesions on the subtending twigs down the peduncles and over the wettable surfaces of the fruits severe infection resulted, the disease uniformly appearing most abundantly on the areas obviously most subject to this type of dissemination; (3) that in all cases where conditions precluded this type of dissemination only sparse infection occurred, the lesions being miscellaneously scattered over the wettable surfaces of the fruits in a

manner suggesting infection from rain-beaten or wind-blown spores; and (4) that even under these severe conditions no infection occurred upon the protected surfaces of the fruits, doubtless due to the fact that these areas are rarely, if ever, thoroughly wet during the more important periods of fruit infection, and consequently both the transfer of spores to such areas and the subsequent development of the fungus are practically precluded.

CONCLUSIONS.

From the evidence presented, it appears to be conclusive that a large majority of fruit infections result from water-borne spores from lesions on the subtending twigs. Considerable dissemination must obviously be accomplished by meteoric water which drips or spatters from spore-bearing areas. Wind dissemination evidently occurs to a limited degree, especially in cases where spores are detached from the parent fungus by chance mechanical agencies, as by the rubbing together of organs of the host plant or by the impact of wind-blown sand particles. It is altogether probable that other general agencies of spore dissemination, such as insects and birds, may play some part in spreading the disease, but no evidence of this has been observed. If it occurs, it is certainly of very minor importance, except, possibly, as a means of transferring spores over relatively long distances.

METHOD OF INFECTION.

The exact method by which the fungus penetrates the cuticle of the various affected organs of the host has not been conclusively determined. While the solution of this problem is necessary to a full knowledge of pathogenesis, the attendant difficulties are such that this would have required the expenditure of more time than would be justified by its importance to this paper. Certain observations and experiments in this connection, however, seem to be worthy of record.

The abundance of naturally and artificially induced infection shows conclusively that the penetration of the fungus is independent of wounds. Consequently, it must normally occur through natural openings, directly through the cuticle, or in both of these ways. Since the problem is presented in its simplest aspect in leaf infection, certain studies of leaf penetration were made, as follows:

Experiment 1.—On July 15, 1915, a potted 2-year-old Early Crawford tree bearing abundant foliage in various stages of development was inoculated by spraying with a water suspension of spores from a 15-day-old Lima-bean agar culture of a twig strain of the fungus. The plant was kept in a moist compartment and sprayed daily with sterile distilled water. Marked inoculated leaves in various stages of development were collected daily and placed in stoppered test tubes in a solution prepared by mixing glacial acetic acid and 95 per cent ethyl alcohol in equal parts. After the leaves were thoroughly bleached, their under (dorsal) surfaces were carefully studied microscopically, previous inoculation experiments having shown that the upper

(ventral) surfaces are not infected. The development of the fungus was easily traced. Material collected 48 hours after inoculation showed abundant germination, the tubes averaging 40 to 60 μ in length. No evidence of penetration, however, was observed at this stage. In subsequent collections, which extended over six days, a slow development of the fungus could be traced, but this appeared to be almost entirely superficial. Frequently germ tubes were traced over stomata, but in no case were they observed to enter them. In certain cases, in material collected on the third day and subsequently, slender colorless hyphae were observed in such positions as strongly to indicate direct penetration of the cuticle, the apical portions being in a slightly lower focal plane than the spores from which they originated. However, the thinness and the delicacy of the cuticle, which on the lower surface of the leaf is usually less than $1\frac{1}{2}$ μ thick, and the fact that the fungus does not penetrate farther into the leaf tissues made it impossible to draw final conclusions from the material at hand. There was no opportunity of extending these studies. These data, however, in conjunction with the fact that penetration through stomata could not put the fungus in its characteristic subcuticular position, leave no reasonable doubt that leaf infection occurs by means of direct penetration of the cuticle.

No special studies of twig and fruit infection have been undertaken. However, since the nature of the surfaces of the very young twigs is so similar to that of the lower surfaces of the leaves, it is to be expected that leaf and twig penetration are of the same type.

In the earliest stages of fruit infection observed in histological preparations, the fungus was found closely appressed to the host cells in the minute depressions surrounding the bases of hairs. These cavities obviously offer exceptionally favorable conditions for infection courts, and it is entirely probable that most fruit infection occurs in this fashion, the development of the fungus being chiefly superficial, in close contact with the cells of the host.

PERIOD OF INCUBATION.

On fruits.—The time which elapses between infection and the macroscopic appearance of fruit lesions has been shown to vary, not only with environmental conditions, but also with the nature and stage of development of the fruit. In the inoculation experiments this period was observed to vary between 42 and 77 days. In nature, with more extreme conditions, it is highly probable that the variations are even greater.

On leaves.—In leaf infection similar variations occur, but they are less marked, since the complicating factor of masking by hairs is eliminated. In the inoculation experiments it was shown that the period of incubation for leaf lesions might vary between 25 and 45 days, and probably more. Under the more extreme conditions of the field, it is likely that the variations are greater.

On twigs.—In the inoculation experiments the period of incubation for twig infections of the early summer closely approximated that of leaf infection. It is evident, however, that great variations in this regard may occur in the case of late twig infections, many of which do not become macroscopic until the following spring.

TIME OF NATURAL INFECTION.

Of fruit.—The inoculation experiments previously reported show that infection may occur from spores applied 10 days after the calyces are shed, but it should be remembered that special precautions were taken to insure the passage of these spores through the difficultly wettable hairy thatch of the fruit. It is evident, however, that such early infection is rare in nature, since (1) the disease may be commercially controlled when the first application of spray is made one month after the petals fall and (2) the interim between this time and the general macroscopic appearance of the disease coincides satisfactorily with the period of incubation of the fungus, as worked out in the inoculation experiments. The chief reasons for this delay appear to be (1) the hindrance of access of spores to the surface of the fruit, due to the difficultly wettable hairy thatch of the peach and (2) the diminution of infection by means of water-borne spores from subtending twigs, due to the upturned position of many fruits during the earlier stages of their development. As the fruits increase in size, the hairy covering becomes thinner and more easily wettable, while, with increased weight, the peaches generally turn downward and become more subject to inoculation by sporiferous meteoric water from infected subtending twigs. Abundant infection usually begins to occur about five to seven weeks after the petals fall and may continue until the fruit matures, but on account of the long period of incubation of the fungus the later infections do not become macroscopically evident.

Of twigs and leaves.—From the results of the inoculation work it is evident that twig and leaf infection may occur whenever viable spores come in contact with tender young twigs or the under surfaces of leaves under conditions favorable for the development of the fungus. Under field conditions in Georgia, however, as is shown by the data given concerning the seasonal development and the period of incubation of the fungus, very little infection occurs on twigs and leaves until several weeks after the petals fall. Subsequently, such infections occur abundantly, with favorable conditions, throughout the season. Important reasons for the fact that the bulk of the twig and leaf infection occurs relatively late are (1) that in the South much of the new wood of the peach tree is formed relatively late and (2) that the conidia borne upon fruit lesions may constitute an important source for infections which, on account of the long period of incubation of the fungus, do not become visible until late in the season.

SOURCES OF NATURAL INFECTION.

Primary.—From the data presented in the preceding topics it is apparent that primary infection results from conidia from overwintered twig lesions. Practically all the fruit infections, especially in the case of early and midseason varieties, come from this source, as

do the earlier infections of twigs and leaves. No other source of infection is known to be available until sporulation occurs on lesions of the current year's production. In northern Georgia this does not usually take place to any considerable degree until early June.

Secondary.—Conidia from lesions of the current year's production constitute the source of secondary infection. On account of the long period of incubation of the fungus, lesions resulting from this type of infection rarely become injurious on the fruit, except, perhaps, on late varieties. On the twigs and leaves, however, as was demonstrated in the inoculation experiments, secondary infections may be very abundant. Under orchard conditions such infections undoubtedly account for a large percentage of the twig and leaf lesions which appear throughout the late summer and fall.

OVERWINTERING OF THE FUNGUS.

In considering the problem of how the fungus passes the winter, three major possibilities demand attention, viz, (1) the overwintering of conidia, (2) the overwintering of the mycelium in dead infected parts, and (3) the overwintering of the mycelium in lesions upon the living host.

Careful studies of infected fruits, twigs, and leaves in late winter uniformly failed to reveal the presence of viable conidia. Furthermore, the evidence furnished by the germination tests previously reported shows conclusively that when exposed under orchard conditions these conidia would not remain dormant and viable over winter. Even if they did pass the winter in minimal numbers, the conditions of infection, as set forth above, would make them a negligible factor in the life history of the fungus.

In the fall of 1913, portions of diseased fruits, twigs, and leaves from Cornelia, Ga., were exposed in the university orchard at Madison, Wis., and allowed to pass the winter. In the following spring conidia were produced in considerable numbers upon the fruit and twig fragments, and the fungus was readily isolated from each of these sources. The leaves, however, were badly decomposed, and the fungus was not identified upon them.

At Cornelia, Ga., during the springs of 1912 and 1913, many overwintered fruits and leaves from trees and from the ground were examined microscopically. The fungus was not definitely identified from any of these sources. It is quite probable, however, that under favorable circumstances the mycelium may survive the winter under orchard conditions upon fallen fruits, twigs, or leaves; but the evidence previously cited seems to prove conclusively that this type of overwintering is of no practical significance in the life history of the fungus.

In connection with this work, careful watch was kept for a possible ascigerous stage of the fungus, but no positive results were secured.

As has been shown in preceding topics, the primarily important overwintering of the fungus is accomplished by the mycelium in lesions on living twigs. Here the organism passes the winter safely, and with the advent of favorable conditions in spring it produces conidia abundantly.

CLIMATE IN RELATION TO THE DISEASE.

Published records from the more important peach-producing districts of the world indicate that scab occurs at its worst in temperate sections where the spring and early summer are moist and the growing season is long, while it is much less prevalent in dry sections or in high altitudes, where the opposite conditions obtain. Likewise, in regions where the disease is abundant it is more prevalent in moist than in dry seasons and on low than on high ground.

In the light of the foregoing life-history studies, the reasons underlying these conditions are evident. Abundant moisture is necessary for spore production, spore dissemination, and infection, while the long growing season increases the period during which these processes may occur.

VARIETIES IN RELATION TO THE DISEASE.

Among writers on this aspect of peach scab, there appears to be a consensus of opinion that varieties differ markedly in the degree in which they are subject to the disease. Selby (1898, p. 221) writes—

Certain varieties of peaches appear more susceptible to scab than others, just as certain varieties of apples suffer more than others from the apple scab.

Scott and Quaintance (1911, p. 11-12) state—

In general, the late varieties are much more susceptible than the early varieties. This is due, in part at least, to the fact that the fruit of the late-maturing varieties is exposed to infection over a longer period and the opportunity for the development of the disease is greater.

While the writer has made no detailed study of these varietal differences, field observations and the life-history work previously reported accord well with the views of Scott and Quaintance. In general, the fruit of the earlier varieties, such as the Greensboro, Carman, and Hiley, is relatively lightly attacked. The midseason varieties, such as the Belle and Elberta, may be moderately or severely diseased, depending upon conditions. Late varieties, such as the Heath, Salway, and Bilyeu, are the most severely attacked.

These conditions are partly explained in the light of the life-history studies. The lateness of infection and the long period of incubation ordinarily preclude very seriously injurious development of the

disease before early varieties are harvested. On midseason varieties under conditions favoring the development of the disease, there is time for very serious injury to result. On late varieties the great increase in opportunities for infection and incubation are attended by consequent increment in the severity of the disease. The earlier varieties as a group are thus more properly designated as disease-escaping than as resistant, since they may be quite seriously scabbed when conditions unusually favor the early development of the disease.

While the period of exposure of the fruit to the attack of the fungus appears to be a major factor in these varietal differences, it is evident that other causes are involved. It has been noted that certain varieties growing in adjacent rows and ripening at about the same time have been attacked by scab in very different degrees and that certain of the earlier varieties are commonly more seriously affected than some of those which ripen later (Table IX). It is also a matter of common observation that seedlings are often especially severely attacked. No attempt has been made to investigate the further causes underlying these variations.

At the writer's request Mr. M. B. Waite, Pathologist in Charge of Fruit-Disease Investigations, Bureau of Plant Industry, has prepared a list of important commercial varieties of peaches grown in the Middle States, with estimates concerning the degrees in which they are subject to scab injury in this territory. These estimates, which are based upon more than 25 years of experience and observations extending over all the important peach-producing districts of the area in question, are incorporated in Table IX.

TABLE IX.—*List of important commercial peach varieties, with estimates of the comparative degrees in which they are subject to injury by Cladosporium carpophilum in the Middle States.*

Variety.	Estimated decrease in market value of unsprayed crop due to scab injury (per cent).		Variety.	Estimated decrease in market value of unsprayed crop due to scab injury (per cent).	
	In aver- age seasons.	In bad seasons.		In aver- age seasons.	In bad seasons.
Alexander.....	25	50	Oldmixon.....	40	80
Rivers.....	40	80	Elberta.....	35	70
Hale Early.....	15	30	Chairs.....	35	70
Waddell.....	30	60	Late Crawford.....	25	50
Carman.....	30	60	Edgemont.....	25	50
Mountain Rose.....	40	80	Stevens.....	30	60
Hiley.....	15	30	Fox (<i>Fox Seedling</i>).....	25	50
St. Johns.....	10	20	Smock.....	40	70
Champion.....	30	60	Heath.....	50	90
Early Crawford.....	15	30	Salway.....	60	90
Belle.....	25	50	Bilyeu.....	70	95
Reeves.....	35	70	Tennessee.....	75	100
Stump.....	30	60			

Supplementary notes by Mr. Waite follow.

Notes supplementing Table IX.—This list gives most of the commonly grown commercial peach varieties of the Middle States in their order of ripening, and comparative estimates of scab injury to unsprayed fruit, in percentage of the value of the crop, in average localities from southern Pennsylvania, Maryland, and Virginia west to Missouri and Arkansas. North of this section, and particularly along the northern limit of peach culture, from New England and New York to Michigan, there is considerable reduction in the severity of the disease. The damage is distinctly less on light, sandy soils than on heavy soils or even on sandy loams. It is greatly reduced at high altitudes. For example, Bilyeu, before the advent of spraying, was considered wholly unfit for commercial planting below 1,500 feet altitude in the Appalachian Mountain belt, on account of its susceptibility to scab, but could be grown successfully at high altitudes. The disease is somewhat more destructive in the Southern States than in the Middle States, and is generally aggravated in moist localities. In arid regions it disappears.

A peach half covered with confluent scab spots, particularly if cracked open, may be considered as without commercial value. A peach badly spotted, with only one-fourth of its area covered, may be considered as of only 50 per cent commercial value in comparison with perfectly smooth fruit. Fruit with even less scab in a season of low prices may be rendered unfit for marketing. With unsprayed trees of Heath, Salway, Bilyeu, Tennessee, and certain seedlings in lower altitudes in the Middle and Southern States it is not rare to have the entire crop rendered commercially worthless by scab.

CONTROL MEASURES.

SPRAYING.

Since the serious economic aspects of peach scab began to be recognized during the early period in the development of Bordeaux mixture, when this newly discovered fungicide was being applied with such marked success in the control of many of the most destructive plant diseases, it is not surprising that the earliest efforts to control this malady consisted almost entirely of spraying experiments with Bordeaux mixture of various formulas. Cobb (1894, p. 386) and Sturgis (1897, p. 271), apparently on a priori grounds, suggested treatments with this fungicide, while Price (1896, p. 840-841) reported decidedly favorable results from three applications of Bordeaux mixture (4-5-50) upon Early China and Mamie Ross. Selby (1898, p. 237-260), in 1895 and 1896, carried out the first extensive spraying experiments, reporting favorable results from the use of Bordeaux mixture. Five years later the same author (1904, p. 67), as the result of seven years' study, states—

For scab prevention, in addition to one spraying before blossoming with some effective fungicide, recent observations indicate the need of two applications of weak Bordeaux mixture [2-2-50] upon trees in foliage; the earlier of these to be made in northern Ohio about June 15; the second, three to four weeks later.

Although this treatment was efficacious and proved satisfactory in certain sections and under certain conditions, so much host injury resulted that Bordeaux mixture never came into general use throughout the United States as a summer spray for the peach.

While many other spraying experiments were reported during this period and subsequently, no material advance was made until Scott (1907 and 1908), realizing that the copper sprays in their present state of development are too toxic for general application upon peach foliage, sought to develop an efficient fungicide which would be applicable to tender-foliaged plants without serious host injury. He conducted preliminary experiments with self-boiled lime-sulphur and reported very promising results in the control of peach scab. The same author (1909, p. 7-12) carried out further similar experiments and recommended (p. 11-12) self-boiled lime-sulphur treatments for the control of this malady. Scott and Ayres (1910) and Scott and Quaintance (1911) confirmed these results by extensive spraying experiments and gave detailed recommendations for the self-boiled lime-sulphur treatments.

Lewis (1910) conducted peach-spraying experiments in which he used, comparatively, self-boiled lime-sulphur, home-boiled lime-sulphur, Bordeaux mixture, and certain proprietary fungicides, each preparation being applied alone and in combination with arsenate of lead. He reports self-boiled lime-sulphur as giving the most favorable results, his recommendations (p. 47) paralleling those of Scott and Ayres (1910).

Clinton and Britton (1911, p. 604-618) sprayed peaches with self-boiled lime-sulphur, potassium sulphid, and certain proprietary sprays. In certain applications, insecticides were added to the fungicides. These authors report most satisfactory results from the self-boiled lime-sulphur and recommend its use.

Blake and Farley (1911, p. 11-30), in an extensive series of peach-spraying experiments, made comparative tests of home-boiled lime-sulphur, self-boiled lime-sulphur, and certain proprietary fungicides. They regarded all the preparations used except self-boiled lime-sulphur and a sulphur paste as too toxic to be applied with safety to peach foliage unless made too dilute to be efficient. They recommend the use of self-boiled lime-sulphur, which they state (p. 26) "is the best fungicide known at the present time for the control of peach scab and brown-rot."

Norton and Symons (1912, p. 266-268), in continuation of previous experiments, tested self-boiled lime-sulphur and various proprietary preparations in peach-scab control. They reported that self-boiled lime-sulphur gave the most favorable results.

These and like experiments appear to show (1) that Bordeaux mixture and various other copper sprays, lime-sulphur, and liver of sulphur, in combination with arsenate of lead, in concentrations sufficiently strong to control scab, are too toxic to be applied generally as summer sprays for the peach; (2) that peach scab may be controlled by spraying with self-boiled lime-sulphur, alone or mixed with arse-

nate of lead, without serious injury to the host; and (3) that sulphur paste may control this disease.

The purposes of the writer's experiments were (1) to test further, in relation to locality, season, and variety, the excellent spray schedules worked out by Scott and others; (2) to test the efficiency and desirability of a sulphur spray in comparison with self-boiled lime-sulphur; and (3) to correlate with control measures a clearer understanding of the nature, cause, and development of the disease.

The spraying experiments¹ were conducted in commercial orchards at Cornelia, Ga., in 1910, 1912, and 1913, and at Hart, Mich., in 1911. More than 150 plats, containing over 10,000 trees, were sprayed, while parallel observations were made upon commercial orchards containing in the aggregate many hundred thousand trees.

In the experiments of 1911, 1912, and 1913, the spray was applied by means of a gasoline power sprayer, double "Friend" nozzles being used. At Cornelia, in 1910, good barrel outfits were employed.

Careful field observations of each plat were recorded throughout the season. At harvest time, in as many cases as was feasible, the fruit from a number of typical trees of each plat, usually 10 to 12, was picked, critically examined, and classified according to the occurrence and abundance of scab, the occurrence of brown-rot, and the salability of the fruit. By carefully noting many thousands of fruits in this fashion and tabulating the resulting data, it was possible to arrive at strikingly accurate and concrete comparisons of the efficiency of the different treatments.

EXPERIMENTS IN 1910 AND 1911.²

The season of 1910 in northern Georgia was very favorable for the development of scab and brown-rot and offered a severe test of the efficiency of the various treatments used. The results were eminently satisfactory, but since they have been reported in brief by Scott and Quaintance (1911, p. 23-26), they will not be considered further here.

In 1911 extensive experiments were conducted at Hart, Mich., on 10 of the more important commercial varieties of that section. Owing to an unusually dry spring and summer, so little scab occurred, even upon unsprayed trees, that little differentiation of results of the various treatments was feasible. Even under these conditions, however, the sprayed fruit appeared to be sufficiently superior to that of the control plats to justify the expense of the treatments. These results will not be considered further in this connection.

¹ Grateful acknowledgments are made to Messrs. A. M. Kitchen, Cornelia, Ga. (1910), H. W. Gebhart and F. Brooker, Hart, Mich. (1911), A. B. Veeder, S. R. Christie, and Laing & Segers, Cornelia, Ga. (1912), and W. B. Hunter, Cornelia, Ga. (1913), for their cordial cooperation.

² These experiments were conducted under the direction of Mr. W. M. Scott, formerly Pathologist, Office of Fruit-Disease Investigations, Bureau of Plant Industry, U. S. Department of Agriculture.

EXPERIMENTS IN 1912.

TREATMENT.

A summary of the treatments of the individual plats and results therefrom is given in Table X. No plat contained less than 40 trees.

TABLE X.—Summary of treatments and results in spraying experiments, Cornelia, Ga., 1912.

Variety and plat.	Treatments.				Results.							
	Spray used. ¹			Dates of application. ²	Count of trees.	Scabbed— ³						
	First application.	Second application.	Third application.			Total fruits.	Slightly.	Commercially.	Badly.	Total.	Culled.	Merchantable.
Carman:												
1.....	Al&lime.....	Al&Sp.....	Sp.....	(1) Apr. 30	10	5,598	P. c. 7.3	P. c. 0.2	P. c. 0	7.5	5.5	94.5
2.....	do.....	Al&S-b l-s.....	S-b l-s.....			107,941	8.2	.4	0	8.6	4.2	95.8
3.....	do.....	do.....	do.....	(2) May 13-14	—	—	—	—	—	—	—	—
4.....	Al&lime.....	do.....	do.....			—	—	—	—	—	—	—
5.....	do.....	Al&S-b l-s.....	do.....	(3) June 1	10	7,659	51.4	35.3	.9	87.3	22.7	77.3
6.....	Control.....	do.....	do.....			—	—	—	—	—	—	—
Elberta:												
9.....	Al&lime.....	Al&Sp.....	Sp.....	(1) Apr. 23-24	10	2,396	39.7	3.4	0	43.1	2.5	97.5
9A.....	do.....	do.....	do.....			—	—	—	—	—	—	—
9B.....	do.....	do.....	do.....	(2) May 15-16	10	5,791	45.1	52.2	.5	97.8	5.0	95.0
10.....	do.....	do.....	Sp.....			—	—	—	—	—	—	—
11.....	Al&Sp.....	do.....	do.....	(3) July 2	10	5,791	45.1	52.2	.5	97.8	5.0	95.0
12.....	Al&S-b l-s.....	S-b l-s.....	do.....			63,294	65.4	6.2	.03	71.6	7.6	92.4
13.....	Al&lime.....	do.....	do.....	(3) July 2	10	5,937	47.4	49.2	1.2	97.8	8.3	91.7
14.....	do.....	Al&S-b l-s.....	do.....			107,620	63.3	5.5	.05	68.8	2.8	97.2
14A.....	do.....	do.....	do.....	(3) July 2	11	4,400	32.7	63.1	3.1	98.9	31.6	68.4
15.....	Control.....	do.....	do.....			—	—	—	—	—	—	—
15A.....	do.....	do.....	do.....			—	—	—	—	—	—	—
Belle:												
16.....	do.....	Al&S-b l-s.....	S-b l-s.....	(1) Apr. 23	7	2,015	35.9	60.0	3.3	99.2	5.9	94.1
17.....	Al&lime.....	do.....	do.....			—	—	—	—	—	—	—
18.....	Al&Sp.....	Sp.....	do.....	(2) May 14	7	3,239	68.5	7.2	.2	75.9	2.8	97.2
19.....	Al&lime.....	do.....	do.....			—	—	—	—	—	—	—
20.....	do.....	Al&S-b l-s.....	S-b l-s.....	(3) June 18	7	2,529	60.2	6.1	.03	66.3	3.7	96.3
20A.....	do.....	do.....	Sp.....			72,077	24.6	71.2	3.3	99.1	9.3	90.7
21.....	do.....	Al&Sp.....	do.....	(3) June 18	7	2,529	60.2	6.1	.03	66.3	3.7	96.3
22.....	Control.....	do.....	do.....			72,077	24.6	71.2	3.3	99.1	9.3	90.7

¹ Abbreviations for sprays used: Al=Arsenate of lead paste (diplumbic), 1½ pounds in 50 gallons. Lime=Stone lime, 3 pounds in 50 gallons. Sp=A proprietary sulphur paste, 5 pounds in 50 gallons (except on plat 9B) a preparation consisting of finely divided sulphur (45 to 55 per cent sulphur guaranteed) with a small amount of organic adhesive material in suspension in water. S-b l-s=Self-boiled lime-sulphur, 8 pounds of lime and 8 pounds of sulphur in 50 gallons.

² The treatments were made, as nearly as feasible, (1) 10 days after the petals fell, (2) one month after the petals fell, and (3) one month before the fruit ripened.

³ Slightly scabbed fruits included those bearing from one to a few scattered, inconspicuous spots; commercially scabbed, those sufficiently marred to detract from their market value but not to render them unmerchantable; and badly scabbed, those rendered nearly or wholly unmerchantable by excessive scab infection.

⁴ Sulphur paste, 8 pounds in 50 gallons.

The condition of the experimental plats is briefly described as follows:

Plats 1-6.—Eight-year-old Carman trees, well grown, but badly neglected and suffering from lack of pruning, cultivation, and fertilization. Fertile clay-loam soil. Orchard elevated and slightly rolling, with excellent air and surface drainage. Had received an imperfect winter application of lime-sulphur. Fairly well pruned in early spring and cultivated throughout the season. Crop good.

This orchard, which had been practically abandoned, had just been bought for planting to apples. It was chosen as offering most adverse conditions for the production of good fruit and a most severe test of the efficacy of the treatments used.

Plats 9-15.—Vigorous, well-grown, well-kept, 8-year-old Elberta trees. Orchard elevated and slightly rolling, with excellent air and surface drainage. Sandy clay soil. Had received a winter application of lime-sulphur. Well pruned, cultivated, and fertilized. Crop good.

Plats 16-22.—Vigorous, 8-year-old Belle trees, well kept, but slightly under size. Sandy clay soil. Orchard elevated and slightly rolling, with good air and surface drainage. Had received the winter application of lime-sulphur. Well pruned, cultivated, and fertilized. Crop good.

RESULTS ON FOLIAGE.

Observations made at frequent intervals throughout the season showed no evidence of spray injury upon any of the plats treated with self-boiled lime-sulphur. In plats 9, 9A, 9B, and 11, however, sprayed with the sulphur paste and arsenate of lead, a considerable amount of "shot-holing" and yellowing of the foliage began to appear about the middle of July. This was followed by some defoliation throughout late July and early August. The fruit of these plats was very highly colored but not injured. The foliage of the parallel self-boiled lime-sulphur plats (12, 13, and 14) was not injured, being quite vigorous, well colored, and free from disease except for a limited amount of leaf injury which possessed the typical characteristics of peach bacteriosis (*Bacterium pruni* Smith). The foliage of the control plat, though less vigorous than that of plats 12, 13, and 14 and not so well colored, showed very little yellowing and defoliation. These facts strongly suggested that the trouble in plats 9, 9A, 9B, and 11 was some type of spray injury.

Inasmuch as each of the earlier treatments had been omitted from one or another of plats 9 to 15, conclusive data appear to be available. The key to the situation seems to lie in plat 10, which was treated in the same manner as the adjacent plats, 9 and 9A, except that the second application was omitted. On this plat, directly adjacent to plat 9, the foliage went through the season in excellent condition, closely approaching that of the self-boiled lime-sulphur plats in vigor and color. Thus, all plats (9, 9A, 9B, and 11) which received the sulphur paste and arsenate of lead in the second application were generally affected, while none of the remaining plats showed any evidence of spray injury. Therefore, it seems conclusive that the injury must have resulted from this treatment.

No experiments were made to test separately and comparatively the action of the sulphur paste and of arsenate of lead. However, since sulphur alone has proved to be one of the safest fungicides known and since the sulphur paste caused no injury when applied alone in the third treatment on plat 10, it seems evident that the

injury resulted from the arsenate of lead. Inasmuch as the second application, being the primarily important scab treatment, was quite heavy, this result is not surprising. The fact that no such deleterious results attended the use of arsenate of lead in combination with the self-boiled lime-sulphur indicates strongly that the addition of lime, as in the first application, would have prevented or minimized the injury. If the lime is necessary as a precautionary measure in the first application it would seem equally so in connection with the sulphur paste in the second.

Though, unfortunately, no plats in which lime was added to the arsenate of lead and sulphur paste in the second application were included in these experiments, the practicability of its satisfactory addition was shown clearly in an adjoining orchard. At the writer's suggestion, the addition of lime, at the rate of 2 pounds to 50 gallons, was made in the second application on the 30,000-tree orchard of the Habersham Orchard Co. In all other respects this orchard was treated similarly to plat 9. The foliage went through the season in excellent condition and the control of diseases was eminently satisfactory. However, the work was, of course, not experimental.

These observations on foliage injury are presented merely as field notes upon what appeared to be a clear case of arsenical injury. They are not set forth as warranting generalizations, but merely as a further warning that, as would be expected, very considerable injury may result under certain conditions from heavy applications of arsenate of lead (diplumbic) with sulphur paste. It should be clearly borne in mind, however, that there was no evidence to indicate that the injury was any greater than it would have been had the arsenate of lead been applied alone.

RESULTS ON FRUIT.

PLATS 1-6: CARMAN.

Results were taken at harvest time in the manner previously described, upon representative trees of plats 1, 2, and 6. In all cases the count trees were selected as typical of the plats which they represent. As it reached the proper stage for shipping, the fruit was gathered in successive pickings by the regular orchard employees, being thus harvested in the same manner and at as nearly as possible the same stage as the rest of the fruit of the commercial orchards. The fruit from each tree was picked separately and promptly turned over to the writer for examination. The records for each tree at each picking were thus kept separately throughout. The summarized results of this count work appear in Table X, while certain facts which can not be shown in tabular form are stated as follows:

Supplementary notes.—Under the conditions of these experiments, inasmuch as the plum curculio (*Conotrachelus nenuphar* Herbst.) injury, scab, and rot were considerably

less severe than usual, all the sprayed plats gave a commercially satisfactory control of these troubles. Plats 1 and 2, however, gave markedly superior results, yielding a quantity and quality of fruit which scarcely would have been credited as possible when the work was begun in the spring.

On plat 3, as would be expected, the insect injury was somewhat worse than on plats 1 and 2, while the scab on plat 4 was materially more apparent than on plats 1 and 2, though not quite so conspicuous as on the control.

On plat 5 scab and curculio were well controlled. Consequently, rot was not very abundant, though it developed to a rather serious extent during the severe conditions which obtained throughout the latter part of the harvest period, when daily rains occurred. The amount of rot which thus appeared was ample to justify the third application, as in the case of plats 1 and 2.

Striking though they are, the tabulated figures do not give a full conception of the real contrast between the sprayed and unsprayed fruit. The former was firm, uniform, and highly colored, passing excellently through the severe conditions of the picking season and carrying to market in good condition. The latter was much inferior in color, uniformity, and texture, ripening rapidly and unevenly, and becoming too soft for shipment unless picked green. The close picking of the control trees lessened the percentage of rot and culls, as the brown-rot fungus attacks the peach most severely after the fruit has entered well into the ripening stages.

These results show (1) that the sulphur paste and self-boiled lime-sulphur, respectively, controlled scab and brown-rot in a highly satisfactory manner, the fruit of plats treated with the two fungicides being of remarkably similar quality, agreeing almost to a per cent in each classification (plats 1 and 2); (2) that in northern Georgia at least two, and preferably three, applications are necessary for the satisfactory commercial spraying of the Carman and similar early varieties; (3) that the timing of the application on plats 1 and 2 was satisfactory; and (4) that the second application was primarily responsible for scab control.

PLATS 9-15: ELBERTA.

The summarized results from the more important Elberta plats appear in Table X. Certain data which can not be included in the table are as follows:

Supplementary notes.—The fruit of plats 9A and 9B was so similar to that of plat 9 and the results on plat 11 were so similar to those on plat 12 that no counts were made from plats 9A, 9B, and 11.

As in the case of the Carman results, the tabulated figures fail to give an adequate conception of the superiority of the sprayed over the unsprayed fruit. At first glance, it would seem, for instance, that a very considerable amount of scab infection had taken place on the sprayed fruit. Such, however, was not the case, the great majority of sprayed fruits classified "slightly scabbed" bearing only one to several small, inconspicuous infections which could be detected only by critical expert examination. Thus, a single scab spot of this type frequently served to classify an otherwise perfect fruit as "slightly scabbed." On the other hand, in the case of the unsprayed fruit, the "slightly scabbed" specimens usually bordered very closely upon the "commercially scabbed" class. Therefore, it is important to note clearly that the scab infection on the fruit of all plats which received the second application was commercially negligible.

These results show (1) that the sulphur paste and self-boiled lime-sulphur, respectively, controlled scab in a highly satisfactory manner and with remarkably similar results (plats 9, 14, and 15); (2) that the omission of the first application materially increased the amount of insect injury and diminished the amount of merchantable fruit (plats 11 and 12); (3) that the second application was, as indicated by previous field experiments and subsequent laboratory studies, primarily responsible for scab control (plats 9, 10, 13, 14, and 15); (4) that in northern Georgia three applications of spray are necessary for the satisfactory commercial control of scab, rot, and the curculio upon the Elberta and similar midseason varieties; (5) that the sulphur paste at the rate of 5 pounds in 50 gallons was in sufficiently strong dosage, giving apparently as good results as 8 pounds in 50 gallons used comparatively (plats 9 and 9B); and (6) that the timing of applications on plats 9 and 14 was satisfactory.

PLATS 16-22: BELLE.

The summarized results from the more important Belle plats are given in Table X. Certain data which can not be incorporated in the table are as follows:

Supplementary notes.—Plats 16 and 18 when carefully noted at harvest time were indistinguishable in their results from plats 20 and 21, respectively, except for the prevalence of a considerable amount of superficial insect injury. Owing to the unusually light attack of the curculio, the omission of the first application was thus attended by very little loss. This condition, however, appears to be quite unusual for the section, and these results do not justify the risk of omitting this treatment in commercial orchards.

The results of plats 17 and 19 were so similar at harvest time that counts were made from plat 17 only. A like similarity occurred in the cases of plats 20, 20A, and 21, results being taken from 21 only.

These results show (1) that the sulphur paste and self-boiled lime-sulphur, respectively, controlled scab in a highly efficient degree and with remarkably similar results (plats 20 and 21); (2) that the omission of any one of these three applications would have been unwise (plats 16, 17, 18, and 19); (3) that the second application was primarily responsible for scab control (plats 17, 19, 20, 21, and 22); (4) that in northern Georgia three applications of spray are necessary for satisfactory commercial results on the Belle and similar midseason varieties; and (5) that the substitution of the sulphur paste for self-boiled lime-sulphur in the third treatment on plat 20A in nowise lessened the efficiency of the schedule, the substitution having the advantage of precluding the possibility of spray-stained fruit at harvest time.

THE SPRAY SCHEDULE.

While this discussion is concerned primarily with peach-scab control, it must consider incidentally the control of brown-rot and the

plum curculio, since in the more important peach-producing sections of the United States east of the Rocky Mountains any commercially successful scab treatment must combine satisfactorily and economically with control measures for these associated troubles.

THE TIME AND NUMBER OF APPLICATIONS FOR MIDSEASON VARIETIES.

Treatment before the blossoming period.—Numerous writers have recommended as the first spray for scab a treatment just before the blossoming period. Sturgis (1897, p. 271), apparently on a priori grounds, suggested this treatment, while Selby (1904, p. 66) includes it in his recommendations. His tabulated results (1898, p. 251–252), however, show no decisive benefit resulting from this application, while, on the other hand, his best control in certain cases occurred on plats which did not receive this treatment. Evans (1911) and others make like recommendations. Scott (1907, 1908, and 1909), Scott and Ayres (1910), Scott and Quaintance (1911), and others showed that scab can be successfully controlled when this winter application is omitted. Clinton and Britton (1911, p. 614; 1912, p. 374) concluded from comparative experiments that this treatment had little or no effect upon scab or rot. They (1912, p. 374) state—

In 1910, all of the trees having this winter treatment gave just as high a percentage of scab * * * as did those not having it, neither lot having any summer treatment. In 1911, all the trees having this winter treatment and three summer treatments did not give any lower percentage either of scab or rot than those that received only the three summer treatments.

Furthermore, the writer's life-history studies previously reported show that at the time of the winter treatment the fungus is so well protected by the cuticle of the host that it would not be feasible to combat it efficiently with any standard fungicide. It appears conclusive, therefore, that a winter application is not necessary for efficient scab control.

Treatment as calyces shed.—Clinton and Britton (1911, p. 614, 617) recommend the application of a suitable fungicide at about the time the calyces are shed. Their data (p. 614), however, do not show any better results from this application in conjunction with two later treatments than from the later treatments alone, and these authors (1912, p. 395) suggest that if any of these applications must be omitted it should be the first. Blake and Farley (1911, p. 19) reported that scab development was considerably checked, though by no means controlled, by a single application of a suitable fungicide when the calyces were being shed. They recommended (p. 26) this treatment in conjunction with two later applications. They did not, however, give a thorough test to the two later treatments alone, using self-boiled lime-sulphur or a sulphur spray. Selby's (1898, p. 251) tabulated data, on the other hand, show no benefit from this

treatment. Selby (1904), Scott (1909), Scott and Ayres (1910), Scott and Quaintance (1911), and others showed conclusively that scab may be controlled to a degree which is entirely satisfactory commercially when the first fungicidal treatment is made about one month after the petals fall. The results of the writer, previously reported, offer further confirmation of this work. When the application is delayed so long as this, slight scab infection is to be expected, but it is usually confined to scattered, inconspicuous lesions about the peduncles. It appears conclusive, therefore, that the application of a fungicide at the time of the shedding of the calyces is not necessary to commercially satisfactory scab control, except possibly under very extreme conditions, though at times it may be of some value, and is relatively inexpensive when an application of arsenate of lead is made for the plum curculio at this time.

Treatment about one month after petals fall.—The results of Selby (1898 and 1904), Scott (1908 and 1909), Scott and Ayres (1910), Clinton and Britton (1911), Scott and Quaintance (1911), Blake and Farley (1911), and others indicate the importance of the application of a suitable fungicide about one month after the petals fall. The results of the writer (plats 9, 10, 13, 14, 15, 17, 19, 20, 21, and 22) further confirm this work, showing clearly that for midseason varieties this is the primarily important treatment for scab.

Treatment three to four weeks before the fruit is harvested.—The work cited in the preceding paragraph indicates the desirability of a further fungicidal treatment. If scab only were considered this would be made about two or three weeks after the preceding application, since previously reported life-history studies have shown that infections which occur later than six weeks before the fruit is harvested are not likely to become injurious. However, the fact that this treatment must, for the sake of economy, serve also as the final spray for brown-rot makes it necessary to delay it until three weeks or a month before the fruit is picked.

4 VARIATION OF SCHEDULE FOR EARLY VARIETIES.

The results of Scott and Ayres (1910), Scott and Quaintance (1911), the writer (plats 1, 2, 5, and 6), and others show that on early varieties commercially satisfactory scab control may be effected by a single thorough fungicidal treatment about one month after the petals fall and that under certain circumstances the later treatment may be omitted without serious loss of efficiency. In such cases the first and second treatments, as recommended for midseason varieties, will suffice. In cases where there is danger of serious outbreaks of brown-rot, however, the omission of the third application seems unwise. In such cases the three applications, as recommended for midseason varieties, should be made.

VARIATION OF SCHEDULE FOR LATE VARIETIES.

Scott and Quaintance (1911) showed clearly that while the treatment recommended for midseason varieties will go far toward controlling scab on highly susceptible late varieties, the addition of an application of the fungicide alone four or five weeks after the second regular treatment, or about eight or nine weeks after the petals fall, may materially increase the efficiency of scab control and thoroughly justify itself economically.

THE FUNGICIDE TO USE.

The first and most difficult requisite of a satisfactory fungicide for the summer spraying of peaches is that it must not be seriously injurious to the host, whether applied alone or in conjunction with a satisfactory internal poison for insects. Furthermore, of course, the spray must be efficient, cheap, and reasonably easy to prepare and apply, and it must not leave seriously objectionable residues upon the fruit at harvest time. From the work of Sturgis (1901), Bain (1902), Scott (1907 and 1908), Lewis (1910), Clinton and Britton (1911 and 1912), Blake and Farley (1911), Norton and Symons (1912), and others, it is clear that Bordeaux mixture, soda Bordeaux, ammoniacal copper carbonate, copper subacetate, potassium sulphid, home-boiled lime-sulphur, and various proprietary preparations of copper, sulphur, and lime-sulphur, in concentrations to be economically efficient, have failed to meet the first of these requirements and are not to be recommended, save possibly under very exceptional conditions, for the summer spraying of peaches. The work of Scott (1907, 1908, and 1909), Scott and Ayres (1910), Lewis (1910), Clinton and Britton (1911 and 1912), Scott and Quaintance (1911), Blake and Farley (1911), Norton and Symons (1912), the writer (plats 2, 6, 14, 15, 20, and 22), and others shows conclusively that self-boiled lime-sulphur, properly prepared and applied, will meet all of the requirements mentioned above and will satisfactorily control peach scab. Clinton and Britton (1912, p. 373-375) report that in their experiments a proprietary sulphur paste controlled peach scab as well as did self-boiled lime-sulphur, but that in certain cases when it was applied with arsenate of lead serious foliage injury resulted. They were inclined to believe, however, that this injury resulted from the insecticide. Blake and Farley (1911, p. 22) reported promising results from the use of the same sulphur paste in combating peach scab, but their experiments were not sufficiently extensive to justify conclusions. Norton and Symons (1912) sprayed peaches with this fungicide, but reported (p. 268) that the results obtained were too variable to be conclusive. The writer's results (plats 1, 2, 6, 9, 14, 15, 20, 21, and 22) indicate that sulphur paste, properly applied, will control peach scab as efficiently as will self-boiled lime-sulphur and

may be used with safety as a summer spray for peaches either alone or with arsenate of lead. In the latter case, however, the same precautions should be taken against arsenical injury that are observed when the lead arsenate is applied alone. It is altogether probable that thorough applications of finely divided sulphur of any type will control peach scab.

From this evidence, the writer recommends for peach-scab control (a) self-boiled lime-sulphur (8-8-50) and (b) finely divided wettable sulphur. With the paste (approximately 50 per cent sulphur) used in the experiments previously reported, 5 pounds in 50 gallons is a satisfactory dosage. These sprays appear to be equally efficient. Self-boiled lime-sulphur is in most sections the cheaper, while wettable sulphur is somewhat easier to apply and leaves a less conspicuous residue upon the fruit. The cheapness of self-boiled lime-sulphur and its efficacy in preventing or diminishing injury from arsenate of lead make it very satisfactory for the first fungicidal application, while the fact that the wettable sulphur leaves little stain upon the fruit makes that the more desirable for the final treatment. While for many cases this combination of the two sprays appears to be the most desirable, the final choice should be made by the individual grower in the light of these facts and of his own needs and preferences.

COST OF TREATMENT.

Selby (1898, p. 260), working in Ohio, estimated that the cost of spraying peach trees was less than $1\frac{1}{2}$ cents per tree for each application in foliage. Scott and Ayres (1910, p. 21) reported that with a power outfit in Georgia they were able to make four applications of summer spray, two containing arsenate of lead (2-50) and three containing self-boiled lime-sulphur (8-8-50) for $5\frac{3}{5}$ cents per tree. The trees were medium-sized 7-year-old Elbertas. These authors considered that under southern conditions three applications should be made for $4\frac{1}{2}$ cents per tree. Blake and Farley (1912, p. 70-71), working in New Jersey with a hand outfit, reported making four summer applications, two containing arsenate of lead (2-50) and three containing self-boiled lime-sulphur (8-8-50) on 5-year-old Elbertas for 5.59 cents per tree. The writer, working under the direction of Mr. W. M. Scott at Cornelia, Ga., in 1910, kept accurate records of the cost of spraying with a hand outfit. These data, which are reported more in detail by Scott and Quaintance (1911, p. 38), show that the cost of three applications, two containing arsenate of lead (2-50) and two containing self-boiled lime-sulphur (8-8-50), on 7-year-old trees was 2.76 cents per tree. The conditions for this work, however, were unusually favorable. At Fort Valley, Ga., where a power outfit was used, but where other conditions were less favorable than at Cornelia, the cost of similar treatments, as reported by the same

authors, was 3.2 cents per tree. These writers state (p. 38) that for these three treatments the cost will range from 3 to 5 cents per tree, depending upon the labor conditions, the size of the trees, the convenience of the water supply, and the equipment used. While in certain sections where labor is exceptionally expensive the cost may somewhat exceed these figures, this estimate appears to be sound.

PROFIT FROM TREATMENT.

The profit from spraying appears in the increased amount, the superior quality, the better keeping and carrying properties, and the enhanced market value of merchantable fruit. Scott and Ayres (1910, p. 19-20), working in Georgia, report that from Elbertas which were sprayed four times the yield of merchantable fruit was ten times that from similar unsprayed trees. By marketing tests they showed, further, that the sprayed fruit from this block sold for 50 cents per crate more than the fruit from the unsprayed trees. Scott and Quaintance (1911, p. 31) report further shipping tests in which sprayed Elbertas sold for 75 cents a crate more than similar unsprayed fruit of the same variety shipped in the same car. Blake and Farley (1911, p. 30) state that the profit secured by spraying at Vineland during the season of 1910 was more than \$1.50 per tree, while the cost of applying the most expensive treatment did not exceed 5 cents per tree. In the experiments conducted by the writer at Cornelia, Ga., in 1910 and reported in part by Scott and Quaintance (1911, p. 23-26), 70 Elbertas (p. 24) which had received three applications of spray, as recommended later, yielded 97.04 per cent of merchantable fruit, while on 70 parallel unsprayed trees only 54.11 per cent of the crop was merchantable. The yield of similarly treated Summerours (p. 25) was 85 per cent merchantable, as compared with 6.49 per cent from the similar unsprayed trees. An additional application on this variety, as recommended later, would have been necessary for a more thorough control of scab and rot. The actual yields in merchantable fruit from 70 representative trees from each of these plats were 113 bushels from sprayed Elbertas, 31.2 bushels from unsprayed Elbertas, 115 bushels from sprayed Summerours, and 3.5 bushels from unsprayed Summerours.

The previously reported results obtained by the writer at Cornelia, Ga., in 1912 show that even in a season when fungal and insect injuries were less serious than usual, the standard spray treatments, as recommended later, increased the percentage yield of salable sprayed fruit, as compared with unsprayed, 17.2 to 18.5 per cent in the case of the Carman, 28.8 to 29.1 per cent in the case of the Elberta, and 6.5 per cent in the case of the Belle, which escaped disease in an unusual degree.

These results show that where brown-rot, scab, and the curculio are serious factors, spraying is not only highly profitable, but that it is indispensable to commercial success.

RECOMMENDATIONS FOR SPRAYING.

SCAB ONLY.

Early varieties.—Spray with self-boiled lime-sulphur, 8-8-50, or wettable sulphur, 5 pounds in 50 gallons in the case of the paste (approximately 50 per cent sulphur) used in the foregoing experiments, about one month after the petals fall.

Midseason varieties.—Spray as for early varieties, adding a similar application about three weeks later.

Late varieties.—Spray as for midseason varieties, adding a third application about one month after the second.

SCAB, BROWN-ROT, AND THE PLUM CURCULIO.

In practice it is rarely desirable to spray for scab alone, since in most sections where scab is seriously injurious brown-rot and the plum curculio must also be combated. In order to secure the most profitable combination treatment, therefore, certain deviations must be made from the ideal individual schedules, while modifications must be made to meet the needs of sections, seasons, and varieties. Recommendations for the control of brown-rot and the curculio are, consequently, inseparable from those for scab, and, though incidental to this paper, must be included. The recommendations for brown-rot are based upon the results of Scott (1907, 1908, and 1909), Scott and Ayres (1910), Scott and Quaintance (1911), and others, and upon unpublished results of the writer. That part of the schedule which relates to insect control has been kindly supplied by Mr. A. L. Quaintance, of the Bureau of Entomology, United States Department of Agriculture.

While for obvious reasons ironclad recommendations are not attempted, the following schedule, subject to intelligent modification,¹ should be applicable in most commercial peach sections of the United States where scab is a serious factor.

Early varieties.—The early varieties, such as the Greensboro, Carman, Hiley, and those with similar ripening periods should be sprayed as follows:

(1) With arsenate of lead and lime about ten days after the petals fall. This application may be omitted in sections where the curculio is not a serious factor.

(2) With arsenate of lead and self-boiled lime-sulphur or finely divided wettable sulphur about a month after the petals fall. If the latter type of fungicide is used, the addition of lime, as in the first treatment, may be a desirable precaution against arsenical injury.

¹ For suggested modifications, see Scott and Quaintance (1911, p. 38-40).

(3) With finely divided wettable sulphur or self-boiled lime-sulphur three to four weeks before the fruit ripens, but not less than four weeks before harvest if self-boiled lime-sulphur is used. This application may be omitted in sections where brown-rot is not seriously injurious.

Midseason varieties.—The treatment recommended for early peaches is applicable, likewise, to midseason varieties, such as the Reeves, Belle, Early Crawford, Elberta, Late Crawford, and Fox. For such varieties, however, the third application is very essential and should not be omitted where brown-rot or scab injury is serious.

Late varieties.—The Salway, Heath, Bilyeu, and varieties with similar ripening periods should be treated as midseason varieties, with the addition of an application of the fungicide alone about a month after the second treatment.

The following concentrations of spray preparations are recommended: Arsenate of lead paste, $1\frac{1}{2}$ pounds (powder, three-fourths pound) in 50 gallons; stone lime, 2 to 3 pounds in 50 gallons; self-boiled lime-sulphur, 8 pounds of lime and 8 pounds of flour of sulphur in 50 gallons; and finely divided wettable sulphur, 5 pounds in 50 gallons in the case of the paste (approximately 50 per cent sulphur) used in the foregoing experiments. Directions concerning the preparation and use of these sprays are given by Scott and Quaintance (1911, p. 33-35).

ORCHARD SANITATION.

While the disposal of orchard refuse is a highly commendable practice and thoroughly justifiable from the standpoint of the control of other diseases, it appears to be of relatively slight importance in peach-scab control, since the lesions on the living twigs constitute the chief source of infectious material. Though it has been recommended that the diseased twigs be pruned out and destroyed, this procedure is manifestly impracticable in view of (1) the great numbers and inconspicuous appearance of the lesions and (2) their occurrence on the fruiting wood. Furthermore, such drastic measures are unnecessary, since the disease is readily and inexpensively controlled by spraying, and little or no injury is done to the affected twigs. Less directly, however, sanitation may be practiced with profit in pruning and growing the trees in such fashion as to facilitate the free access of air and sunlight and in providing for as good air and surface drainage of the orchard as is feasible.

RESISTANT VARIETIES.

Since the severity of scab injury varies materially with varieties, it should be remembered that the disease may be in some degree avoided by growing those varieties which are less severely attacked. However, inasmuch as these are chiefly the earlier peaches, it is not feasible to accomplish very much with this method in practice.

Furthermore, since even on the worst affected varieties the disease may be efficiently and economically controlled by spraying, the use of varieties which are in some degree disease escaping or resistant is unnecessary, though advisable when other factors are equal.

SUMMARY.

Peach scab (*Cladosporium carpophilum* Thüm.) manifests itself in serious spotting and cracking of the fruit and superficial injuries on twigs and leaves.

In the United States the disease has been reported from 34 States, which include practically every important peach-producing district east of the Rocky Mountains. Its occurrence has also been recorded in Austria, Canada, Holland, Australia, southern Europe, and South Africa.

Among the fungous diseases of the peach in the United States east of the Rocky Mountains, scab ranks next to brown-rot in economic importance. In many sections, before satisfactory control measures were developed it rendered unprofitable the growing of certain valuable commercial varieties. Unless controlled, it would be a serious menace to successful commercial peach culture in many of the most important peach-producing districts of the Southern, Eastern, and Central States.

The peach-scab fungus was first described by Von Thümen (1877), who assigned it the binomial *Cladosporium carpophilum*. Oudemans (1901) described as *Fusicladium carpophilum* Oud. a fungus growing on fallen young peaches. He lists as a synonym *Cladosporium carpophilum* Thüm., but neither gives Von Thümen credit for the specific name nor states his reasons for transferring the fungus to the genus *Fusicladium*. Aderhold (1901) expressed the belief that *C. carpophilum* Thüm. and *C. cerasi* (Rbh.) Aderh. are identical, but he admittedly failed to adduce sufficient evidence to justify this conclusion. Until further evidence is presented, the writer accepts the name *Cladosporium carpophilum* Thüm. for the peach-scab parasite.

The primarily important diagnostic characters of the fungus are the short, erect, more or less flexuous, one to several septate, rarely branched, olivaceous conidiophores and the ovate-fusiform, obtuse to apically subacute, continuous or 1-septate, light fuscous conidia, which are borne acrogenously, singly or in simple or branched chains.

The fungus was isolated from peach fruit, twigs, and leaves, respectively, in single-spore strains, which were grown comparatively upon more than 30 media. The cultural differences between strains from different organs of the host were no greater than those observed in strains from the same organ. The fungus grew well upon this wide range of media and showed only minor variations upon the different substrata.

Moisture favors growth. Desiccation checks growth and favors the formation of chlamydospores.

The minimal temperature for growth on favorable nutrient substrata is less than 2°; the optimal, between 20° and 27°; and the maximal, about 32° C.

Strong diffuse light favors sporulation.

Normal spores germinate readily in sterile distilled water, rain water, and a large variety of nutrient solutions and agar preparations. The alternate wetting and drying of germinating spores do not appear to be seriously injurious unless the changes are very frequent during the early stages of germination.

The minimal temperature for germination in water or in a favorable nutrient solution is less than 2°; the optimal, between 20° and 27°; and the maximal, slightly above 32° C.

Peach fruit, twigs, and leaves were inoculated with single-spore strains of *Cladosporium carpophilum* from peach fruit, twigs, and leaves, respectively. Each strain produced typical infection upon fruit, twigs, and leaves, with the exception of the leaf strain upon the fruit. In this case the experimental fruits were destroyed by trespassers before the results were available. Each strain of the fungus was repeatedly reisolated and was found to possess the typical morphological and cultural characters of *C. carpophilum*. Fruit infection was induced by direct inoculation with scrapings from abundantly sporulating twig lesions. Conclusive positive results from inoculations with *C. carpophilum* have not been previously reported.

Scab infection ordinarily appears shortly prior to the ripening period of early varieties and may continue throughout the season.

Spore production from fruit, twig, and leaf lesions may begin as soon as infection becomes macroscopic and may continue throughout the development of the lesions. The most abundant sporulation occurs on overwintered twig lesions during the spring and early summer following infection.

Freshly produced, normal conidia from fruit, twig, or leaf lesions are capable of germinating in sterile distilled water, rain water, or a variety of nutrient media.

When dry the conidia persist tenaciously upon their sporophores. In water, however, they quickly become detached. Meteoric water appears to be the most important agent in their liberation and dissemination.

In the inoculation experiments the period of incubation of the fungus upon the fruit was observed to vary from 42 to 77 days. Upon twigs and leaves it varied from 25 to 45 days. In nature the variations are undoubtedly even greater.

Little natural infection occurs until four to six weeks after the petals fall. Subsequently, under favorable conditions it rapidly becomes more abundant and may continue throughout the season.

Primary infection results from conidia from overwintered twig lesions. Spores from lesions of the current year's production may induce secondary infection.

The fungus overwinters in the mycelial stage in the lesions on living twigs. There is no evidence that any other type of overwintering is of any practical importance in the life history of the parasite, although it has been shown that the mycelium may survive the winter on fallen fruit and twigs.

Peach scab occurs at its worst in temperate sections where the spring and early summer are moist and the growing season is long. It is much less prevalent in dry sections and in high altitudes where the opposite conditions obtain.

Varieties vary markedly in the degree to which they are subject to scab injury. In general, early varieties are not very seriously affected. Midseason varieties may be moderately or severely attacked. Late varieties are usually the most severely affected. The period of exposure of the fruit to the attack of the fungus is a major factor in these differences. There are, however, varietal differences which are independent of the ripening period of the fruit. These have not been explained.

It has been shown conclusively that the disease may be controlled in a highly satisfactory manner by spraying with self-boiled lime-sulphur or with finely divided wettable sulphur and that the scab treatment may be satisfactorily combined with the control of brown-rot and the plum curculio. (For summarized recommendations, see pp. 59-60.)

Under average conditions, the cost of spraying 7-year-old to 10-year-old peach trees for scab, brown-rot, and the plum curculio (three treatments, as recommended on pp. 59-60) should not exceed 5 cents a tree.

In the writer's experience, the merchantable fruit from trees properly sprayed in accordance with the foregoing recommendations has rarely amounted to less than 95 per cent of the total yield, even under severe conditions, while its quality has uniformly been much superior to that of the unsprayed product.

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SECOND ANNUAL REPORT OF BIRD COUNTS IN THE UNITED STATES, WITH DISCUSSION OF RE- SULTS.

By WELLS W. COOKE, *Assistant Biologist*.¹

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INTRODUCTION.

A preliminary enumeration of the birds on many farms of the United States, made during the summer of 1914, was so satisfactory and the information obtained so important that it was decided to repeat the work in 1915. In the second effort it was planned to cover as many different kinds of country as possible and particularly to secure more records and more reliable data concerning birds in the Gulf States and in the region from the Plains westward.

The returns from the 1915 bird count were on the whole very satisfactory. As in 1914, the largest number of reports from any single section came from the Northeastern States—that is, the States north of North Carolina and east of Kansas—but they are particularly gratifying because of their close agreement with returns of 1914 from the same section. When an enumeration of birds was first suggested the project was the subject of much good-natured banter and some criticism from those who declared the scheme utterly visionary.

¹ Shortly after writing this report, and following a very brief illness, Professor Cooke died, March 30, 1916. He was a prominent ornithologist and the foremost American authority on the migration of birds.—EDITOR.

NOTE.—This second report on the number and relative abundance of wild birds (see Dept. Bull. 187, issued Feb. 11, 1915) is for the information of workers and others interested in the protection and increase of birds.

The reports of 1914 from farms of the Northeastern States agreed so well among themselves and with results obtained by other persons in previous years that they seemed to warrant the belief that their average closely approximated the actual facts. The counts of 1915 from the same region serve to strengthen this belief and to make it practically certain that the conclusions drawn as to the number of birds on these farms is very nearly accurate.

A word of explanation may be offered as to just what results were expected from the work, and also as to what phases of the bird population question are not covered by these first two years of bird counting.

The most important factor of bird life concerns its relation to human beings and has to do with its influence for good in helping the farmer destroy the foes of his crops. Hence to ascertain the numbers of birds in the trees and shrubbery on the acres actually devoted to crops and immediately contiguous thereto is more important economically than on other lands, and these numbers have been most in mind in the work thus far conducted. The principal question of these two years has been, therefore, What kinds of birds and how many pairs of each kind nest on the farms in the area surveyed and remain on or near them during the middle of the summer, when crops grow fastest and also suffer most from insect enemies?

So far as the farms of the Northeastern States are concerned, the average of the 1914 counts was about one pair of birds to the acre, and as this number is so nearly the same as presented by the additional work of 1915, it may be said with reasonable assurance that this is the average bird population of that part of the Northeastern States actually devoted to agriculture.

The work has not yet reached the stage where the general average found—in the Northeastern States of nearly 800 pairs of birds to the square mile—may be subdivided and an estimate made of the number of pairs of each kind. For some of the commonest and most widely distributed species, like the robin and English sparrow, however, the reports are probably sufficiently numerous to permit an approximate estimate.

The different kinds of birds on a farm are so much more variable than the average number of birds per acre that it will require many more counts to serve as reliable bases for formulating averages of species. Two contiguous farms of 100 acres each may each support 100 pairs of nesting birds, yet the kinds of birds on the two farms may vary widely, according as one farm is upland, and the other lowland; one devoted to grain raising, and the other, in permanent pastures, to dairying; one supporting a growth of hardwood trees, the other showing nothing but evergreens.

Many phases of bird population have scarcely been touched by the two years' work. How many birds to the acre inhabit permanent marshes? What effect on the number of birds has the presence of a stream, a river, a pond, or a lake? What is the average effect of altitude or latitude on bird life? These and many other questions are interesting and important, but may not yet be answered.

Another important question concerning bird population, which is partially covered by the counts of 1914 and 1915, relates to the numbers of birds inhabiting those areas near large centers of human population which are not devoted strictly to agricultural purposes, as city lots, parks, cemeteries, etc. It is, of course, desirable to have the greatest possible numbers of native birds in all such places, and some of the returns show in a very striking manner how quickly and abundantly the birds respond to efforts to make these sections better adapted to a large bird population.

A brief explanation should be made regarding the qualifications needful in an observer to result in a satisfactory enumeration. The Biological Survey has for many years had several hundred migration observers throughout the country reporting bird arrivals and departures. If a person is familiar with only half a dozen of the commonest birds and is well situated to note the earliest arrivals among these species, his notes on the birds he knows are just as valuable, so far as they go, as those of one who has a wider bird acquaintance. But in counting birds such partial knowledge is worse than useless. If a bird count is to have value, it must be true not only as far as it goes, but it must tell the whole truth. This requires that the enumerator be able to identify with certainty all the birds nesting on the area he covers, or be able to give a recognizable description of those he is unable to name. Lack of such knowledge has made unusable some reports which were undoubtedly correct as to the species listed, but which showed their incompleteness by absence of records for the smaller and less conspicuous birds.

Letters of criticism of the method used for counting the pairs of birds have been received. Of course if one is living on the area on which he reports and has the time and inclination to go over the ground repeatedly, day after day, until each nest has been actually located, his report would be more accurate and valuable than one made by ear by the method outlined in the circular of instructions. But this would require twenty to fifty times as many hours' observation, and hardly more than one person in a hundred would feel inclined or be able to devote so much additional time to the work. Some six years of such work done by the writer convinced him that a person who knows the birds by their songs can use the method advocated and obtain, with the expenditure of a minimum of time and effort, a count that will compare favorably in accuracy with the most pains-

taking and exhaustive hunting out of the nests themselves. During two different years, in less than three hours of one morning, he made a survey of a 50-acre field which was supporting a bird population of some 30 species and about 75 pairs, and obtained results so nearly correct that continued observation on the field for the remainder of the season made scarcely any change in the figures thus obtained.

PLANS FOR THE 1915 COUNTS.

As the returns from the 1914 counts had shown that the method pursued gave satisfactory results, the same method was employed in 1915. A circular of detailed instructions was sent to each person who offered to help in the work. This was widely distributed; calls for additional bird enumerators also were inserted in the principal



FIG. 1.—Places from which bird-count reports were received in 1915.

ornithological journals; and in various other ways the matter was brought to the attention of those interested in birds. As a result about 315 reports, from every State in the Union, except Utah and Nevada, were received in 1915. As shown by the accompanying map (fig. 1), these are fairly well scattered over the country, but the largest proportion comes from the northeastern part of the United States, as was the case in 1914.

RESULTS IN THE NORTHEASTERN STATES.

The bulletin publishing the results of the bird enumeration of 1914¹ discussed at some length the work on farms of the Northeastern States. The most interesting phase of the 1915 returns is a consideration of the two counts from the same section to see whether the agreement is close enough to indicate accuracy in the 1914 conclusions.

¹Bull. 187, U. S. Dept. Agr., Feb. 11, 1915.

The number of new reports received from this section in 1915 was almost exactly the same as the total number received in 1914. This new material has been treated with reference to the same points considered in 1914, and the comparison of the results of the two years is given in the subjoined table.

The average farm in the Northeastern States, according to the 1910 census, contains 108 acres, and a farm of this size was used as the basis of the calculations for each year.

TABLE I.—*Results of counts in northeastern United States.*

	1914	1915	Average for 2 years.
	<i>Acres.</i>	<i>Acres.</i>	<i>Acres.</i>
Average area covered by each count.....	58	64	61
Plowed land.....	17	21	19
Hay land.....	8	6	7
Orchard.....	4	5	5
Woodland.....	3	9	6
Land around buildings.....	3	3	3
Permanent meadow.....	8	6	7
Pasture land.....	15	14	14
	<i>Pairs.</i>	<i>Pairs.</i>	<i>Pairs.</i>
Average bird population on each area covered.....	69	80	75
Average bird population for each 100 acres of the area covered.....	119	125	122
Average bird population on each 100 acres of isolated woodland.....	175	199	187
	<i>Acres.</i>	<i>Acres.</i>	<i>Acres.</i>
Average area not covered by the count in each farm.....	50	44	47
Plowed land.....	15	13	14
Hay land.....	7	6	6
Woodland.....	18	16	17
Meadow and pasture.....	10	9	10
	<i>Pairs.</i>	<i>Pairs.</i>	<i>Pairs.</i>
Probable average bird population in the woodland.....	31	32	32
Probable bird population on the remainder of the area.....	14	12	13
Probable bird population on each 108-acre farm (estimated from average of count area and area not covered).....	114	124	119

The results of the counts of 1915 agree so very closely with those of 1914 as to indicate the strong probability that each represents on the average a close approximation to the truth.

Some 25 persons who sent in reports of bird counts in 1914, taken on farms in the Northeastern States, made reports the next year of counts taken on the same areas. The average of these for 1914 is 117 pairs of native birds to each 100 acres of farm land, while the average for 1915 is 122 pairs.

Combining all the 1915 counts from farms in the Northeastern States with those of 1914 which were not repeated in 1915—that is, combining the counts of all the different farms received in the two years—gives the following results, expressed in the same terms as those used in the report of the 1914 enumeration:

The average enumeration area on farms in the Northeastern States is 61 acres, i. e., it consists on the average of the farm buildings and the grounds surrounding them together with approximately

half the land of the farm, leaving an average of 47 acres of land farthest from the buildings not covered by the count. Thus two problems are presented: First, how the 61 acres covered by the census compare with the average farm; and, second, how the remaining 47 acres compare in bird population with the 61 acres chosen.

That portion of the average farm covered by the enumerations contained 32 per cent of plowed ground and 10 per cent of hay land, which, according to the 1910 census, is nearly the average percentage for the farms in this section of the United States. There is, however, a great difference in the relative sizes of orchards; these farms contained 7.3 per cent of orchard, whereas the average for the North-eastern States is only 1.2 per cent, or, in other words, the area selected for the bird enumeration contained six times as many acres of orchard as the average. Each area also contained the farm buildings with accompanying shade trees, ornamental shrubs, small fruits, and vegetable gardens, forming the most favorable nesting sites on the farm and affording the largest quantity of food per acre. There is no doubt that the average 5 acres immediately surrounding the farm buildings contain more birds' nests than any other 5 cultivated acres on the farm. As the farms selected contained orchards larger than the average and as orchards are especially preferred for nesting sites by many kinds of birds, the areas selected evidently have a bird population denser than that of farm lands as a whole.

During each of the years 1914 and 1915, counts were made on isolated areas of woodland, and the average of all reports in the two years gives a bird population of 187 pairs to each 100 acres, while the farm land supported 122 pairs per 100 acres. It is evident, then, that comparatively small areas of woodland contiguous to cleared and cultivated land offer better attractions as nesting sites than land which is wholly under cultivation, and contain a correspondingly larger number of birds' nests.

The 47 acres not covered by the two-year counts on each of these farms consisted on the average of 14 acres of plowed ground, 6 acres of hay land, 17 acres of woodland, and 10 acres of meadow and pasture. If the 17 acres of woodland contain on the average, as they probably do, 32 pairs of birds, the other 30 acres would have to support a bird population of 26 pairs to give these 47 acres the same bird population per acre as the part of the farm where the buildings are situated. It is not probable that the 30 acres would have 26 pairs, but they may easily have half that number, which, added to the population of the woodland and of the enumeration area, would make a total of 119 pairs on 108 acres, practically an average of 1 pair to the acre for the land in farms in the North-eastern States.

RESULTS IN OTHER SECTIONS.

In the report on the 1914 bird count it was stated concerning the data received that year from the whole of the United States outside the northeastern section—

Less than a dozen reports came from the South Atlantic and Gulf States, and the number is no larger from the States west of the Rocky Mountains; while the reports from the Plains States—North Dakota to Oklahoma—are too few to be used as representing average conditions in this region. These three divisions, the South, the West, and the Plains, are so diversified in climate and agricultural conditions and vary so widely in their bird life that many more bird censuses must be available before generalizations can be made for the whole country and reliable conclusions drawn.

The reports received in 1915 from the South, the West, and the Plains, instead of yielding a satisfactory bird return from these districts, serve rather to accentuate the difficulties of the problem. Deductions from a few of these, following, will show the wide variations and indicate the complexity of bird life in these parts of the United States.

COUNTS IN THE PLAINS REGION.

Of a number of reports received from the Plains region from Oklahoma to North Dakota, only those were selected which seemed to have resulted from counts made under about average conditions. These covered an average area of 56 acres, divided into 15 acres of plowed land, 5 acres of hay land, 1 acre of orchard, 3 acres of woodland, the farm home with the other buildings and farm garden, and the remainder, 29 acres, divided into about one-fourth meadow and three-fourths pasture. The percentage is a little smaller than the average for these States in plowed land and hay land, about the average in meadow and pasture, and considerably above it in woodland and orchard. As these last two are the largest factors in the size of the bird population, it follows that these enumeration areas probably have a larger bird population per acre than the average for the States as a whole.

The average of these reports shows 70 pairs of nesting birds of 22 species on the 56 acres, or at the rate of 125 pairs to the 100 acres, precisely the same as for farms in the Northeastern States, which contained the farm home and exceptionally favorable conditions for a large bird population.

But while these figures are probably entirely correct for the part of the farm which contains the buildings, it is not possible to estimate from any data yet received the bird population on the remainder of the farm outside the enumeration area. The farms in the Plains region are large, averaging 297 acres each, as compared with only 108 acres in the Northeastern States. The part of the average Plains farm not covered by the bird count consists of 241 acres,

divided into 92 acres of plowed land, 27 acres of hay land, 3 acres of woodland, 34 acres of improved meadow and pasture land, and the remainder, 85 acres, of wild, treeless, native prairie. The average bird life per acre on such land is naturally much less than on the part of the farm selected for the enumeration. How much less, the data in hand are not sufficient to determine. Anyone who has ridden over the native prairie knows how seldom birds are seen, and an attempt was made at Sisseton, S. Dak., to obtain a numerical statement of this scarcity. On a tract of 40 acres of prairie pasture land adjoining the Sisseton town site, but having better than average conditions, in that a stream of water, bordered with brush, crossed the tract, the following were found nesting: Killdeer, 2 pairs; prairie horned lark, 3; Sennett nighthawk, 2; lark bunting, 2; and meadow-lark, 3; a total of 12 pairs on 40 acres, or at the rate of 30 pairs to 100 acres, as compared with the 125 pairs to 100 acres of the farm land.

Some suggestive figures in this connection come from Onaga, Kans., where a tract of 80 acres of native pasture, crossed by a creek with a narrow fringe of native timber and occupied at one end by a small cornfield, supported a population of 31 pairs of native birds of 22 species, or in the proportion of about 40 pairs to 100 acres. The adjoining 40 acres, containing the farm home, a 5-acre orchard, and 6 acres of groves, was the summer home of the same number of kinds of birds represented by 49 pairs, or at the rate of 122 pairs to 100 acres.

REPORTS FROM THE ROCKY MOUNTAIN STATES.

The foregoing records from the Plains region are from the part east of the one hundredth meridian, where the average annual rainfall is more than 20 inches and where crops are raised successfully without irrigation. To the west, as the rainfall diminishes, the native bird population on the open prairie decreases until in some of the more desolate sections it almost disappears.

A little west of the one hundredth meridian, near Hobbs, N. Mex., in the extreme southeastern corner of the State, one tract of 80 acres, all native pasture except a 20-acre field of milo maize, had a bird population of 22 pairs representing 9 species; a neighboring 80 acres, with only 10 acres in milo maize, showed 17 pairs of 8 species; while in the same township still a third 80 acres, none of which had ever been disturbed by the plow, was supporting only 13 pairs of 5 species, notwithstanding each of these equal areas contained a set of farm buildings with windmill and tank. The average of these three counts is 17 pairs to 80 acres, or 21 pairs to each 100 acres.

Still farther west, in the irrigated district of western Colorado, two reports have been contributed showing the effect of irrigation on the density of bird life. The first area consisted of 320 acres of irrigated

orchard, near Grand Junction, the trees from 3 to 6 years old; the area was interspersed with small fields of alfalfa, grain, and root crops, and contained about ten sets of farm buildings, sheds, and yards for live stock. The native birds were represented by 116 pairs of 17 species (in addition to a colony of 65 pairs of violet-green swallows, most of which had come within the last few years), 5 pairs of English sparrows, and 12 pairs of the introduced California quail; a total of 198 pairs of birds on the 320 acres. Just above this irrigated land lay a tract of 320 acres in its original wild state, of low hills and small gullies; the hills sparsely covered with sage, saltwort, and other desert plants, and the gullies lined with bushes. Its bird life consisted of the following pairs: Burrowing owl, 3; Arkansas kingbird, 1; Say phoebe, 1; desert horned lark, 5; western lark sparrow, 2; white-rumped shrike, 2; and rock wren, 3; a total of 17 pairs of 7 species. The irrigated land supported a bird population at the rate of 66 pairs to 100 acres, while on the contiguous nonirrigated land the bird life shrank to 5 pairs to 100 acres.

A 40-acre tract on the outskirts of Tombstone, Ariz., containing in one corner a few houses with their yards, but for the most part covered with a sparse growth of desert shrubs, "not heavy anywhere, but quite general," and with no surface water, had a bird population of 50 pairs of 26 species, of which only 4 species were seed-eaters and the rest insectivorous. At a little distance from the town a 40-acre tract of "semidesert" covered with a rather heavy growth of brush, mostly less than 6 feet high, showed 31 pairs of 16 species. No enumeration has yet been made on the real desert. In the mountains of Arizona, near Flagstaff, a tract of 70 acres at about 7,100 feet elevation, covered with western yellow pine and Gambel oak, supported a bird population of 31 pairs of 18 species.

A public park in Missoula, Mont., with exceptionally favorable conditions for bird life, showed 59 pairs of 20 species on 40 acres. Along the shore of Flathead Lake, Mont., 45 acres of woodland had 67 pairs of 24 species. A tract of 48 acres near Missoula, Mont., with $6\frac{1}{2}$ acres in orchard and the rest in native prairie, furnished a home in the orchard for 16 pairs of birds, while only 4 pairs could be discovered on the 40 acres of shrubless prairie.

These examples make it plain that there is a much smaller bird population per acre west of the one hundredth meridian than in the Northeastern States. Just how much smaller can not be estimated from the reports so far received.

Probably no State in the Union has greater variations in bird life than California. A few examples will show some of these, though it will require many more bird counts than those so far made to furnish an adequate basis for estimates of averages. A plot of 20 acres of the campus of the University of California, with conditions

for birds much more favorable than average, showed 87 pairs of 23 species of native birds. A 60-acre tract of wooded hillsides near Gilroy, Cal., was supporting 36 pairs of 10 species. This is close to what would be expected in the Eastern States under similar conditions.

There is no place on the farm where the help of birds is more needed than in the orchard, and the following counts show how the birds congregate where food, shelter, and building sites are closely associated. The numbers of nesting pairs in a tract near Gilroy, Cal., containing an orchard of 30 acres of apricots, prunes, peaches, and grapes, and about 8 acres of pasture and creek bottom, the farm home and other buildings, and many large native trees, are as follows: Oregon towhee, 4; California towhee, 12; valley quail, 5; killdeer, 1; green heron, 3; California woodpecker, 3; red-shafted flicker, 7; western bluebird, 8; western meadowlark, 1; Bullock oriole, 2; Arkansas kingbird, 2; Traill flycatcher, 4; black phoebe, 6; Lawrence goldfinch, 15; lazuli bunting, 1; barn owl, 3; dotted canyon wren, 2; western winter wren, 7; long-tailed chat, 1; California shrike, 2; tree swallow, 5; cliff swallow, 12; California jay, 4; Allen hummingbird, 6; western blue grosbeak, 1; black-headed grosbeak, 8; house finch, 18; western mourning dove, 6; western chipping sparrow, 10; Pacific nighthawk, 2; russet-backed thrush, 2; western lark sparrow, 7; green-backed goldfinch, 2; and English sparrow, 4; a total of 176 pairs of 34 species on 38 acres.

A similarly dense, though less varied, bird population in a 52-acre peach orchard is shown by a count made near Port Clinton, Ohio. This showed 108 pairs of common farm birds, a colony of 36 pairs of purple martins, and 6 pairs of English sparrows, or a total of 150 pairs of 29 species.

ESTIMATED BIRD POPULATION OF THE SOUTHERN STATES.

Bird counts made in Florida show an average of 77 pairs of native birds of 20 species and 5 pairs of English sparrows on 83 acres. The enumeration areas average 4 per cent of plowed land, 21 per cent of woodland, and the remainder open meadow or pasture land. The average of the farms of the State is 12 per cent of plowed land and 60 per cent of woodland, so that the proportion in the enumeration areas does not at all represent average conditions in that State, and the counts can not be used in estimating the average bird life of the State.

Reports from Louisiana show an average of 95 pairs of birds of 29 species on 53 acres, of which 39 per cent is plowed land, 18 per cent woodland, and 41 per cent pasture, while the average farm of the State contains 87 acres, of which 28 per cent is plowed land, 41 per cent woodland, and 28 per cent pasture.

The enumerations from Texas average 91 pairs of birds of 21 species on 60 acres, composed of 43 per cent plowed land, 17 per cent woodland, and 40 per cent pasture; while the average farm of the State contains 270 acres, divided into 15 per cent plowed land, 25 per cent woodland, and 60 per cent pasture.

The average of all counts received from the Southern States, North Carolina, Arkansas, and Oklahoma to Florida and Texas, is 76 pairs of birds of 23 species on a farm of 58 acres, which consists of 33 per cent plowed land, 2 per cent hay land, 24 per cent woodland, and 41 per cent meadow and pasture land. The average farm for this section contains 120 acres, divided into 24 per cent plowed land, 2 per cent hay land, 35 per cent woodland, and 39 per cent meadow and pasture. The enumeration areas thus differ too radically from the average farm conditions to allow safe generalizations, and yet it is worthy of notice that the average for the census areas in this southern section is 131 pairs of nesting birds to 100 acres, while for the Northeastern States the corresponding figure is 125 pairs, and for the Plains region 125 pairs. There is probably more than a mere coincidence in the close agreement of these figures, and they seem to indicate that on the average the farmhouse area and the approximately 60 acres surrounding it support about the same bird population—76 pairs of nesting birds—in all the States east of the one hundredth meridian.

There is still left unsolved the problem of the bird population on the areas in the South and in the Plains region which are not included in the reports. These areas in the Northeastern States constituted only 41 per cent of the total land of the farms, while in the South they form 52 per cent of the whole, and in the Plains region 81 per cent.

From the 59 per cent of the land covered by the count it is possible in the Northeastern States to estimate with fair accuracy the birds on the 41 per cent not covered, but it is not at all safe to generalize in the South, with less than half the farm area represented by the count, and still less so in the Plains region, where less than a fifth of the area is included.

THE NUMBER OF BIRDS CAN BE INCREASED.

The most important fact brought out by the 1914 count was that the average bird population on the farms of the United States can be largely increased by protection and furnishing food and shelter. The 1915 count presents several more instances of a numerous bird population following well-directed efforts for its increase. A farm of 65 acres near Westerville, Ohio, comprising plowed land 23 acres, hay land 22 acres, pasture 5 acres, orchard 5 acres, house and garden plot 2 acres, and swamp and wooded

creek borders 8 acres, showed a population of 110 pairs of native birds and 25 pairs of English sparrows, or about double the average for the State. A farm of 78 acres near Strasburg, Ohio, with about the same proportion of the different fields, had 126 pairs of native birds and 8 pairs of English sparrows, also about double the average. A farm of 40 acres near Middletown, Conn., containing 10 acres of plowed land, 3 acres of woodland, 5 acres of pasture, 12 acres of orchard, and 20 acres of meadow, had a bird population of 165 pairs of native birds, 8 pairs of English sparrows, and 15 pairs of starlings; a total of 188 pairs, or more than four times the average. A farm of 40 acres at New Hope, Pa., called "The Hedges," from its numerous osage orange hedges, and divided into plowed land 15 acres, woodland 2 acres, orchard 5 acres, and grassland 18 acres, supported a bird population of 136 pairs of native birds, 17 of English sparrows, and 1 of the starling; a total of about four times the average.

These examples are all of farms that are used for ordinary farming purposes, and where no attempt has been made to attract an extra number of birds by winter feeding or by putting up nesting boxes. The large bird population is due solely to absolute protection and to leaving abundant chances for favorable nesting sites.

THE BERWYN, PA., BIRD COUNT.

As noted in the report of the 1914 enumeration, the first published bird count in the United States was that made in 1901 at Berwyn, Pa., by Mr. Frank L. Burns. After a lapse of 13 years Mr. Burns in 1914 repeated the count on the same area, and the results have lately been published.¹ His enumeration area consisted of 640 acres, divided approximately into 27 per cent woodland, 16 per cent gardens and shaded lawns, about 30 per cent plowed land, and the remainder, about 27 per cent, covering pasture land, drives, highways, and railroads. The tract is thus somewhat more favorable for birds than the average of the lands covered in 1914 and 1915 by the Biological Survey reports. In his second count Mr. Burns found 617 pairs of native birds on the 640 acres as compared with 588 pairs in 1901, or an average of 97 pairs of native birds to 100 acres as compared with the 100 pairs estimated for 1914 by the Biological Survey for the farms of the Northeastern States. If English sparrows are included, however, Mr. Burns's total is 112 pairs to 100 acres, as compared with the 105 pairs found by the Biological Survey in 1914. Mr. Burns finds 95 pairs of English sparrows on the 640 acres, or at the rate of 15 pairs to 100 acres, where the Biological Survey's average is 5 pairs. Mr. Burns finds 15 pairs of English sparrows to each

¹ Burns, Frank L., Second Sectional Bird Census, 1914, Taken at Berwyn, Chester County, Pa. *Bird-Lore*, XVII, 109-111, March-April, 1915.

100 pairs of native birds, while the Biological Survey's estimate is 5 pairs. Based on his count, Mr. Burns estimates 165,000,000 individual English sparrows in the United States east of the Mississippi River, but this may be somewhat too high for the whole area, since the English sparrow is especially partial to human society and the square mile worked on by Mr. Burns contained more than one person to the acre, or a human population thirty times as dense as the average for farm land in the United States east of the Mississippi River, and several times the average density for the whole land including cities.

SOME NOTABLE REPORTS.

The most elaborate report to the Biological Survey in 1915 was that of the campus of Cornell University, at Ithaca, N. Y. Its 256 acres was divided into six blocks, and the survey of each was made by a different person, the whole being in charge of Prof. Arthur A. Allen, of the university. Following is a description of each of the six blocks:

Block A, 22 acres, hillside pasture with a few trees; block B, 34 acres, hillside planted with scattered groups of trees and shade trees about residences, with very little shrubbery; block C, 87 acres, containing lawns, shade trees, a little shrubbery, and most of the university buildings; block D, 24 acres, about one-third woodland, containing residences with shade trees and some shrubbery; block E, 64 acres, a clover field, a small nursery, a little woodland, and many new buildings; block F, 25 acres, a hillside pasture covered with a thicket of thorn apple and containing a stream.

It is interesting to note the wide variations in the bird population of the various sections. Block C, which contains the university buildings and therefore has the largest human population, hundreds of students passing and repassing all day, has less than the average of native birds but swarms with English sparrows, in numbers almost equal to the total of the native birds. Block D, containing residences, with their shade trees and shrubbery, has the greatest density of native bird population—84 pairs on 24 acres; and blocks A and F, hillside pastures, though supporting a population of native birds considerably above the average for the State, are almost free from English sparrows. (See Table II.)

Another count, representing great and painstaking work, was made by M. S. Crosby on Grasmere Farms, near Rhinebeck, N. Y. A 210-acre section containing 92 acres of woodland, 38 acres of plowed land, 25 acres of meadow, 40 acres of orchard, and 15 acres of lawns, drives, gardens, and buildings, was found to have a bird population of 54 different kinds represented by 366 pairs, or an average of 174 pairs of native birds to 100 acres, nearly the same as on the Cornell University campus.

TABLE II.—*Number of nesting pairs on each of six blocks of the Cornell University campus.*

Species.	Blocks.						Total.
	A.	B.	C.	D.	E.	F.	
Screech owl.....	1			1			2
Spotted sandpiper.....						1	1
Kingfisher.....						1	1
Hairy woodpecker.....				1			1
Downy woodpecker.....					1	1	2
Flicker.....	2		1	1	1	1	6
Chimney swift.....			4				4
Ruby-throated hummingbird.....			1		1		2
Phoebe.....	1	1			2	2	7
Wood pewee.....	1	2	3	6	4	3	19
Least flycatcher.....		1	1			3	5
American crow.....				1			1
Bobolink.....					1		1
Cowbird.....	1			2	1	2	6
Meadowlark.....	1	1	1		1		4
Baltimore oriole.....	3	2	7	4	1	4	21
Bronzed grackle.....			2				2
American goldfinch.....	3		2	2	11	5	23
Vesper sparrow.....		1	1		3	2	7
Savannah sparrow.....			4		3		7
Chipping sparrow.....	7	4	18	9	6	3	47
Field sparrow.....		1			1		2
Song sparrow.....	4	6	3	5	2	11	31
Scarlet tanager.....				1			1
Cedar waxwing.....	2				1	2	5
Red-eyed vireo.....		1	4	5	2	1	13
Warbling vireo.....			3	1			4
Yellow-throated vireo.....				4	2	1	7
Yellow warbler.....	2	2	11	2	1	12	30
Louisiana water-thrush.....				2			2
Maryland yellow-throat.....		2					2
Redstart.....		1		8	5	1	15
Catbird.....	1	2	3	2	1	7	16
House wren.....	1	1	1	1			3
White-breasted nuthatch.....	1			3			4
Chickadee.....	1	1	1	1			4
Wood thrush.....		1		1			2
Wilson thrush.....	1			5	1	1	8
Robin.....	8	36	35	15	6	11	111
Bluebird.....	1	1					2
Total pairs of nesting native birds.....	42	66	106	84	58	75	431
English sparrow.....	3	15	87	15	17	4	141
Ring-necked pheasant.....	1						1
Total number of different species.....	21	19	21	26	24	22	42
Total pairs of nesting birds.....	46	81	193	99	75	79	573
Acres per block.....	22	34	87	24	64	25	256
Nesting pairs of native birds per 100 acres.....	186	200	122	350	77	300	166
Nesting pairs of English sparrows per 100 acres.....	14	44	100	62	27	16	56
Total nesting pairs per 100 acres.....	205	244	222	412	104	316	225

In comparison with the above may be placed a report from Rantoul, Ill., on a farm of 400 acres, of which 315 acres were in corn and oats, and of course practically destitute of birds' nests, leaving only 85 acres to support the 88 pairs of native birds found on the place. Such farms are very common throughout the central corn belt, and while the 88 pairs are about the average for the 85 acres, the farm as a whole shows an average of only 22 pairs to the 100 acres.

The count for 1914 showed an average of 6 pairs of robins and 5 pairs of English sparrows for each farm (of 108 acres) covered. The accuracy of these figures has been called in question by individuals who felt sure that the English sparrow was by far the most

abundant bird in the Northeastern States. The reports for 1915 in this part of the Union bear out the estimates for 1914 that the robin is the more numerous, since the averages are 8 pairs of robins and 6 pairs of English sparrows for each farm. The average of all reports for the two years shows 7 pairs of robins and $5\frac{1}{2}$ pairs of English sparrows for each farm covered.

VARIATIONS IN BIRD LIFE FROM YEAR TO YEAR.

A most interesting and instructive report has been received from Mrs. A. B. Morgan, of Woodstock, Vt., giving the results of enumerations for each of the last eight years on a tract near Woodstock. The tract contains 92 acres, 20 acres of which is woodland, the balance being devoted to permanent pasture and the usual crops of a Vermont farm. The conditions on the farm have scarcely changed during the eight years and the bird life has not much altered—84 pairs of birds in 1915 as compared with 87 pairs in 1908—but it is interesting to note the wide variation in both kinds and numbers of each registered in the annual counts.

The total number of species nesting on the place in the eight years aggregates 49, while the highest number in any one year is 44 and the lowest 35, a range of from 90 per cent to 72 per cent of the total. The average number of nesting pairs per year is 82, with variations from 77 to 87, or an average variation of 3 per cent and a maximum variation of only 6 per cent. These variations have been attributed chiefly to the depredations of hawks. (See Table III.)

A tract of 50 acres at Viresco, Va., came under the writer's observation in 1907. It consists of woodland, 21 acres; plowed land, 5 acres; permanent pasture, 15 acres; and the remainder, 9 acres, brushy land along a stream and on a hillside. At that date much of the land not in woods had lately ceased to be cultivated and was growing up in brush, while the underbrush had just been thoroughly cleared out of all the woods. In the last eight years the underbrush has worked back into the woods, while a great increase has taken place in the brush and young trees along the stream and on some 3 acres that were formerly cultivated. During all the years bird life has been rigorously protected, but there has been no extra bird feeding either winter or summer and no putting up of bird boxes, with the exception of a single small martin house; this, however, was scorned by the martins, which are on several neighboring farms, but was used fitfully by bluebirds, house wrens, and crested flycatchers.

A bird count was made by the writer in each of the last five years, and the results show a steady and pronounced gain in the number of kinds of birds nesting about the place, and a still greater gain in the

total number of nesting pairs. Indeed, the gain in this latter respect, 69 per cent in the five years, is more than may be explained by the growth of bird food and shelter on the place and is probably due to the entire freedom from disturbance which the birds have come to recognize.

TABLE III.—*Kinds of birds, and number of pairs of each, nesting each year from 1908 to 1915 on a tract of 92 acres near Woodstock, Vt.*

Species.	1908	1909	1910	1911	1912	1913	1914	1915
Bluebird	1	1	1	1			1	1
Robin	2	2	2	1	1	1		1
Wood thrush			1	1	1	1	2	2
Wilson thrush	2	2	2	2	3	3	2	2
Hermit thrush	4	4	4	4	4	4	3	3
White-breasted nuthatch	1	1						
Black-capped chickadee	3	3	3	2	1	2	3	3
Catbird	1							
Brown thrasher	1	1	1					1
Black and white warbler	1	1	1	1	1	1		1
Yellow warbler	1	1						
Black-throated blue warbler			1			1	1	1
Chestnut-sided warbler	2	2		2	2	2	2	2
Black-throated green warbler				1	1	1	1	1
Oven-bird	2	2	2	2	2	2	2	3
Maryland yellow-throat	1			1		1		1
Redstart	1		1	1	1	1	1	
Red-eyed vireo	3	3	3	3	3	3	3	3
Yellow-throated vireo	1	1						1
Solitary vireo	2	2	2	2	2	2	2	2
Barn swallow	2	2	3	3	3	4	4	1
Scarlet tanager	1	2	1	1	1	1	1	1
Purple finch	1	1						1
American goldfinch	1	1	1	1	1	1	1	1
Vesper sparrow	12	12	12	12	12	12	12	11
Savannah sparrow	4	4	3	3	3	3	2	3
Chipping sparrow	1	1	1	1	1	1	1	1
Field sparrow	2	2		2	2	2	2	3
Song sparrow	7	7	6	6	6	6	6	9
Rose-breasted grosbeak	1	1	1	1	1	1	1	1
Indigo bunting	1	1	1	1	1	1	1	1
Baltimore oriole	1	1						
Prairie horned lark								1
Kingbird	1	1	1	1	1	1	1	1
Crested flycatcher	1	1	1	1	1	1	1	1
Phoebe	1	1	1	1	1	1	1	2
Wood pewee	2	2	2	2	2	2	2	2
Least flycatcher	1	1	2	2	1	1	1	1
Ruby-throated hummingbird	1	1	1	1	1	1	1	1
Chimney swift	3	3	3	3	3	3	3	1
Nighthawk	1		1					
Hairy woodpecker	3	3	3	3	3	3	3	2
Downy woodpecker	2	2	2	4	4	3	2	2
Yellow-bellied sapsucker		1	2	4	4	4	4	4
Flicker	2	2	2	2	2	2	2	2
Black-billed cuckoo	1	1	1	1				1
Screech owl	1	1						
Ruffed grouse	1	1	1	1	1	1	1	1
Upland plover	1	1	1	1	1	1	1	1
Total number of different species	44	43	38	38	35	37	35	42
Total pairs of nesting birds	87	85	79	82	78	81	77	84

It is interesting to note the change in the character of the bird population from year to year. While 42 kinds of birds nested on the place in the course of the five years, the greatest number in any one year was only 34, while each year a dozen or more kinds of birds nested within sight of the 50 acres, but not within the enumeration area itself. (See Table IV.)

TABLE IV.—*Kinds of birds, and the number of pairs of each, nesting on a 50-acre tract at Viresco, Va., during each of the five years, 1911 to 1915.*

Species.	1911	1912	1913	1914	1915	Species.	1911	1912	1913	1914	1915
Bluebird.....			1		1	Song sparrow.....	6	6	6	5	3
Southern robin.....	1					Field sparrow.....	3	3	4	4	7
Wood thrush.....		1	1	2	2	Chipping sparrow.....		1	1	1	1
Carolina chickadee.....		1	1		1	Grasshopper sparrow.....	1	1	1		
Tufted titmouse.....	1	1	1	2	2	Orchard oriole.....				1	
House wren.....	1		2	1	1	American crow.....		1			1
Carolina wren.....	1	1			1	Blue jay.....					1
Brown thrasher.....			1			Acadian flycatcher.....		1	1	1	2
Catbird.....	3	2	4	5	7	Wood pewee.....	2	1	2	3	2
Black and white warbler.....	1	1	2	2	3	Phoebe.....	2	1	1	1	3
Parula warbler.....		1				Crested flycatcher.....	1		1	1	1
Oven-bird.....	3	4	4	6	6	Kingbird.....		1	1		
Maryland yellow-throat.....	4	4	5	3	5	Ruby-throated hummingbird.....			1		
Chat.....	2	2	1	3	2	Whip-poor-will.....	1	1		1	1
Hooded warbler.....	1		1	1	2	Downy woodpecker.....	1	1	1		1
Redstart.....	1	2	2	2	4	Hairy woodpecker.....				1	
White-eyed vireo.....	1	1	3	3	2	Mourning dove.....					1
Yellow-throated vireo.....	1	2	2	5	2	Bob-white.....					1
Red-eyed vireo.....	2	3	4	9	7						
Rough-winged swallow.....	1	1	1	1	1	Total number of different species.....	27	30	32	29	34
Scarlet tanager.....	1	2	2	2	1						
Indigo bunting.....	3	3	1	3	3	Total pairs of nesting birds.....	48	53	63	74	81
Cardinal.....	1	2	2	2	2						
Towhee.....	2	1	2	2	1						

THE POSSIBILITIES FROM BIRD PROTECTION.

To increase the number and variety of birds about the home, whether in the country or in the city, has become the laudable desire of an increasingly large number of persons. Among the reports are examples of such decided successes in these endeavors that a few in detail will be of interest.

Two city blocks, 10 acres in all, in the town of Aiken, S. C., have for many years been liberally supplied with bird food and water. In the summer of 1915 the following nests were counted: Blue jay, 14; red-headed woodpecker, 11; mockingbird, 9; brown thrasher, 8; catbird, 7; cardinal, 6; wood thrush, 4; orchard oriole, 1; towhee, 1; English sparrow, 4; total, 10 species and 65 nesting pairs. This shows a large number of nesting birds comprising a comparatively small number of species, the blue jay and the red-headed woodpecker being the most numerous.

At Olney, Ill., Mr. Robert Ridgway has devoted 8 acres of land to homes for birds. His aim is to have the greatest possible variety, and of course as many individuals of each as is consistent with this, but a great number of different kinds is considered more important than mere numbers of individuals. As a result of more than ordinarily favorable natural conditions, supplemented by the planting of different kinds of shrubbery for bird food and shelter, furnishing a superabundance of nesting boxes, and supplying an unlimited quantity of food all the year and water through the summer, these 8 acres have become the summer home of 70 pairs of native birds of 31 species, as follows: Mourning dove, 13; screech owl, 2; yellow-billed cuckoo, 1;

red-headed woodpecker, 1; flicker, 2; chimney swift, 1; ruby-throated hummingbird, 1; kingbird, 1; crested flycatcher, 2; wood pewee, 2; alder flycatcher, 1; blue jay, 3; cowbird, 1; meadowlark, 1; orchard oriole, 2; Baltimore oriole, 1; bronzed grackle, 3; goldfinch, 1; chipping sparrow, 1; field sparrow, 1; towhee, 1; cardinal, 2; indigo bunting, 1; Maryland yellow-throat, 1; catbird, 3; brown thrasher, 3; house wren, 8; tufted titmouse, 1; Carolina chickadee, 1; southern robin, 7; bluebird, 1. Mr. Ridgway's experience with some of these birds in their relations to their fellows may be stated in his own words.

The red-headed woodpecker, although one of our most strikingly handsome birds, and in many ways a most interesting one, is, unfortunately, extremely selfish and aggressive. Our single pair prevented any other woodpeckers (the downy, hairy, and red-bellied) from nesting in any of the boxes, drove two pairs of flickers and one pair of crested flycatchers from boxes which they had chosen, and even attacked the purple martins whenever they alighted on the box put up for them. * * * The house wren is equally tyrannical, and no other small bird can nest in his vicinity. Several pairs of Carolina chickadees and tufted titmice, and a pair of Bewick's wrens that had been with us all winter, would have nested in boxes near the house but for the rascally house wrens, who, though possessing boxes of their own, drove the other birds away.¹

His most interesting experiences, however, were with the blue jays and the grackles. The blue jays were very troublesome, destroying fully 90 per cent of the eggs in the first-built nests and even killing and partly devouring half-grown young of the mourning dove. It became necessary to "discourage" the blue jays and the grackles to the extent of 15 pairs of the former and some 50 pairs of the latter before the smaller birds had a fair chance for existence. Parenthetically it may be remarked that on the grounds of the Department of Agriculture at Washington, D. C., the grackles have been known to feed upon newly hatched English sparrows, while the young of the grackles, and to even a greater extent of the English sparrows, also, similarly suffer from attentions of fish crows.

Quite different from Mr. Ridgway's experience with house wrens is that of Mr. Gilbert H. Grosvenor, at his summer home, Wild Acres, in Maryland, a few miles from Washington, D. C. Here, as a result of several years' endeavors, he has a colony of house wrens which in 1915 numbered 19 pairs, all in boxes put up for them in the immediate neighborhood of the house, and yet other birds also were numerous, and in the 5 acres surrounding the house there nested, in 1915, the following additional pairs: Flicker, 3; southern robin, 8; catbird, 3; bluebird, 3; orchard oriole, 2; yellow warbler, 1; brown thrasher, 1; chipping sparrow, 3; phoebe, 2; barn swallow, 1; indigo

¹ Ridgway, Robert, *Bird-Life in Southern Illinois*. Bird-Lore. XVII, 1-7, 91-103, Jan.-April, 1915.

bunting, 1; grasshopper sparrow, 1; song sparrow, 2; meadowlark, 1; red-headed woodpecker, 1; kingbird, 2; field sparrow, 1; Carolina wren, 1; Maryland yellow-throat, 1; screech owl, 1; towhee, 1; English sparrow, 6; and last, but not least, a flourishing colony of 70 pairs of purple martins; in all a total of 24 species and 135 pairs on the 5 acres—the 1915 record for density of bird population.¹

The report of the 1914 bird counts credited Chevy Chase, Md., as having the highest record for that year. This same area in 1915 showed a satisfactory increase in the number of nesting birds, the kinds and the pairs of each being as follows: Southern robin, 19; Carolina chickadee, 2; tufted titmouse, 2; white-breasted nuthatch, 3; cedar waxwing, 2; cardinal, 2; song sparrow, 12; field sparrow, 1; goldfinch, 1; meadowlark, 1; blue jay, 3; red-headed woodpecker, 3; downy woodpecker, 1; screech owl, 1; bob-white, 1; purple grackle, 13; flicker, 3; mourning dove, 1; chipping sparrow, 9; towhee, 1; brown thrasher, 4; chimney swift, 3; house wren, 14; oven-bird, 1; yellow warbler, 1; Maryland yellow-throat, 2; redstart, 2; catbird, 17; wood thrush, 14; yellow-throated vireo, 4; red-eyed vireo, 11; kingbird, 1; crested flycatcher, 1; scarlet tanager, 2; indigo bunting, 1; orchard oriole, 1; Baltimore oriole, 1; wood pewee, 8; yellow-billed cuckoo, 1; English sparrow, 19; a total of 40 species and 189 pairs on 23 acres. A half-acre lot in this area belonging to Dr. S. W. Mellott was the home during 1915 of 20 pairs of birds representing 14 different species, 4 wood thrush nests being the greatest number of any one kind.

A few miles from Indianapolis, Ind., is a tract of 44 acres, known as Woollen's Garden, set aside in 1897 as a bird sanctuary, one of the first—if not the first—of the kind in the United States. In 1909 this was deeded to the city of Indianapolis to be maintained perpetually as a public park where bird life should be carefully protected. It consists of 12 acres of cleared and cultivated land and the remainder of heavily wooded hills and ravines. During 1915 the following pairs of birds nested within its limits: Robin, 4; crested flycatcher, 8; wood pewee, 4; wood thrush, 10; tufted titmouse, 8; cerulean warbler, 10; yellow warbler, 2; redstart, 3; Kentucky warbler, 2; hooded warbler, 1; worm-eating warbler, 1; yellow-breasted chat, 1; Maryland yellow-throat, 2; sycamore warbler, 1; oven-bird, 11; red-headed woodpecker, 1; downy woodpecker, 4; bluebird, 1; phoebe, 3; blue jay, 2; catbird, 2; brown thrasher, 1; bronzed grackle, 2; field sparrow, 4; chipping sparrow, 5; song sparrow, 2; vesper sparrow, 2; grasshopper sparrow, 2; red-eyed vireo, 10; warbling vireo, 3; yellow-throated vireo, 3; cardinal, 3; flicker, 2; indigo bunting, 7;

¹ Mr. Grosvenor gives an interesting account of the birds enumerated on Wild Acres, in *Bird-Lore*, XVIII, 77-84, March-April, 1916.

belted kingfisher, 1; chimney swift, 8; crow, 8; kingbird, 1; sparrow hawk, 1; red-tailed hawk, 1; goldfinch, 12; ruby-throated hummingbird, 3; mourning dove, 2; towhee, 4; yellow-billed cuckoo, 2; green heron, 1; cedar waxwing, 2; killdeer, 1; spotted sandpiper, 1; night-hawk, 2; Acadian flycatcher, 1; alder flycatcher, 2; least flycatcher, 1; Carolina wren, 1; Bewick wren, 2; house wren, 1; whip-poor-will, 2; barred owl, 1; Carolina chickadee, 1; Baltimore oriole, 1; blue-gray gnatcatcher, 1; scarlet tanager, 2; a total of 62 different kinds of birds represented by 193 nesting pairs. This is by far the highest record of all the reports received, in the variety of bird life, but in the average of pairs per acre it is exceeded by several.

These examples, given in detail, show bird lovers what surprisingly satisfactory results may follow persistent and intelligent efforts to attract birds.

SUMMARY.

The second count of the birds of the United States corroborates in general the results obtained by the preliminary work of 1914.

In northeastern United States the average farm contains 108 acres. If the counts in 1915 covered 64 acres, showing a bird population on this part of the farm of 80 nesting pairs, and a probable 44 pairs on the remaining 44 acres, the total of 124 pairs might be credited to the farm of 108 acres.

An average of the returns of counts shows that on farms where counts were made in that part of the Plains region east of the one hundredth meridian and in the whole of the Southern States, for the part of the farm surrounding the farm home there is almost exactly the same density of bird population—for the former, 125, and for the latter, 131 pairs of nesting birds to each 100 acres—but the counts so far received do not furnish a sufficient basis for estimating the birds on the remainder of the farm.

The data received tend to indicate that the western part of the Plains, the Rocky Mountain region, and the Pacific slope contain a smaller number of birds per acre than the Eastern States, but as yet no numerical statement may be attempted.

The further counts made in 1915 emphasize the statement of a year ago, that birds are too few on the farm and that their numbers may be largely increased by protection and a little care in furnishing natural food and shelter. A bird population of 70 pairs of native birds of 31 species on 8 acres, at Olney, Ill.; 135 pairs of 24 species on 5 acres, at Wild Acres, Maryland; 193 pairs of 62 species on 44 acres, at Indianapolis, Ind.; and 189 pairs of 40 species on 23 acres, at Chevy Chase, Md., a half acre of which showed 20 pairs of 14 different species, all indicate how largely birds will respond to food, shelter, and protection.



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WM. A. TAYLOR, Chief



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THE GRAZING INDUSTRY OF THE BLUEGRASS REGION.

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INTRODUCTION.

Grazing bluegrass¹ with horses, mules, cattle, sheep, or hogs is the leading agricultural industry of southwestern Virginia, the adjoining sections of West Virginia and Tennessee, the northwest-central portion of West Virginia, and a large area of central and western Kentucky. For the sake of convenience, as well as to emphasize the importance of bluegrass in that area, this section of country is referred to in this bulletin as the "bluegrass region," a term which is often thus applied. (Fig. 1.)

While pastures consisting in larger or smaller part of bluegrass cover about one-fourth of the improved farm land of the northern part of the Mississippi Valley and eastward to the Atlantic coast, the farm practice in utilizing these pastures over the greater part of that area differs considerably from that of the sections above mentioned. Finishing beef cattle on grass, without grain, is not popular through most of the corn belt. Buyers usually discriminate against grass-fed stock; so while cattle may graze the pastures during the summer, they are either fed grain while on grass or are finished during the winter on grain. In the bluegrass region the cattle are finished on grass alone. Some farmers in this region feed sufficient grain during the winter to keep the 2 and 3 year old cattle gaining in flesh and graze them until

¹ *Poa pratensis*.

July, when they are marketed. The most common practice is to winter the cattle as cheaply as possible and market them in the succeeding fall, when the grass begins to fail. That the quality of these steers is good is attested by the fact that many thousands of them have been exported. (Fig. 2.)

With the exception of central Kentucky, most of the bluegrass lands are unsuited to general-crop farming. They are often too rocky or too steep to be plowed; yet these grazing lands sell readily for \$75 to \$150 an acre. (Fig. 3.)

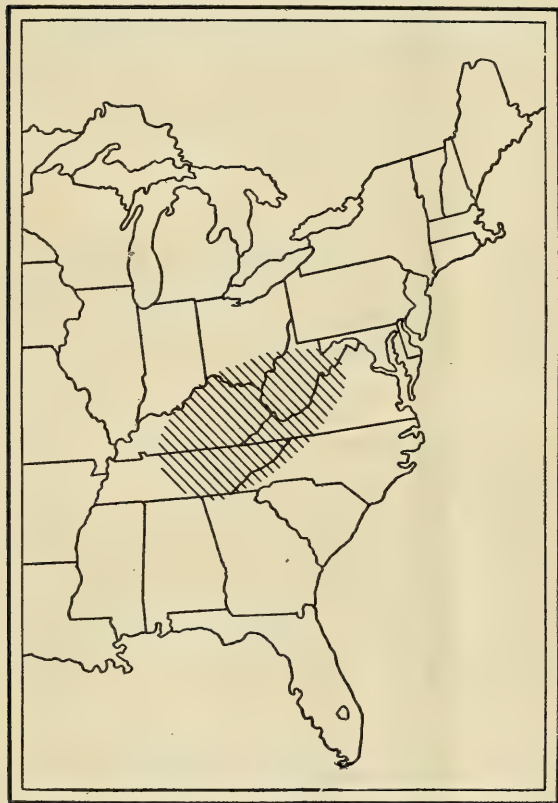


FIG. 1.—Outline map of the eastern United States, showing by shaded lines the region where bluegrass pastures predominate.

to a family and produce sufficient forage to winter as many animals as can be pastured on the remainder of the farm. The grazing farms usually range from 300 acres upward. There appears to be no limit to the area of grazing land which a good business man can manage. There are many farms of several thousand acres.

THE DIFFERENT GRADES OF BLUEGRASS PASTURES.

There appear to be marked differences in the fat-producing qualities of bluegrass, depending apparently on the character of the soil on which it is grown. Practically all of the grass-fed export cattle are

The mildness of the winters in this section, which allows grazing through most of the year and thus reduces the cost of wintering, is perhaps the principal reason why grazing is a more important industry here than in the regions farther north where blue grass is equally well adapted.

There is very little bluegrass land for sale, and when an estate is put on the market it is usually purchased by citizens of the same community. A well-balanced farm in the bluegrass region consists of enough tillable land to give a living

produced on the limestone clays. Other soils may produce luxuriant grass, but the cattle fail to finish properly; they may do all right until they are 2 years old, when they are usually sold to the farmers who have limestone pastures.

Ellett¹ has shown that there is a wide variation in the protein content of Kentucky bluegrass grown in different localities. The protein in the water-free material ranges from 10.22 to 19.98 per cent. It is interesting to note that the grasses analyzing the highest in pro-



FIG. 2.—Steers grazing in the bluegrass region. Many thousands of such steers intended for export are finished on grass.

tein were grown in localities well known for the excellence of the grass-fattened cattle produced.

EFFECT OF WINTER GRAZING ON THE SOD.

There is no question that it is more economical to winter cattle which have free range over a pasture in the bluegrass region than to feed them in small yards. It requires an abundance of grass at all times to produce 350 to 400 pounds of gain on a steer between May 1 and October 1, and there should be considerable grass left when the cattle are sold. This is utilized by the newly purchased stockers.

¹ Ellett, W. B. The bluegrass of southwest Virginia. Va. Agr. Exp. Sta. Bul. 180, p. 89-96. 1909.

Some graziers save fields of bluegrass especially for winter grazing. The consensus of opinion is that this winter grazing does no harm, although many prefer to keep the stock off the pastures for a few weeks when the grass is beginning to grow in the spring.

Feeding hay or corn fodder on the poorest spots of a pasture is a very effective means of improving the stand of grass. (Fig. 4.) An objection often made to the use of a silo is that it necessitates the

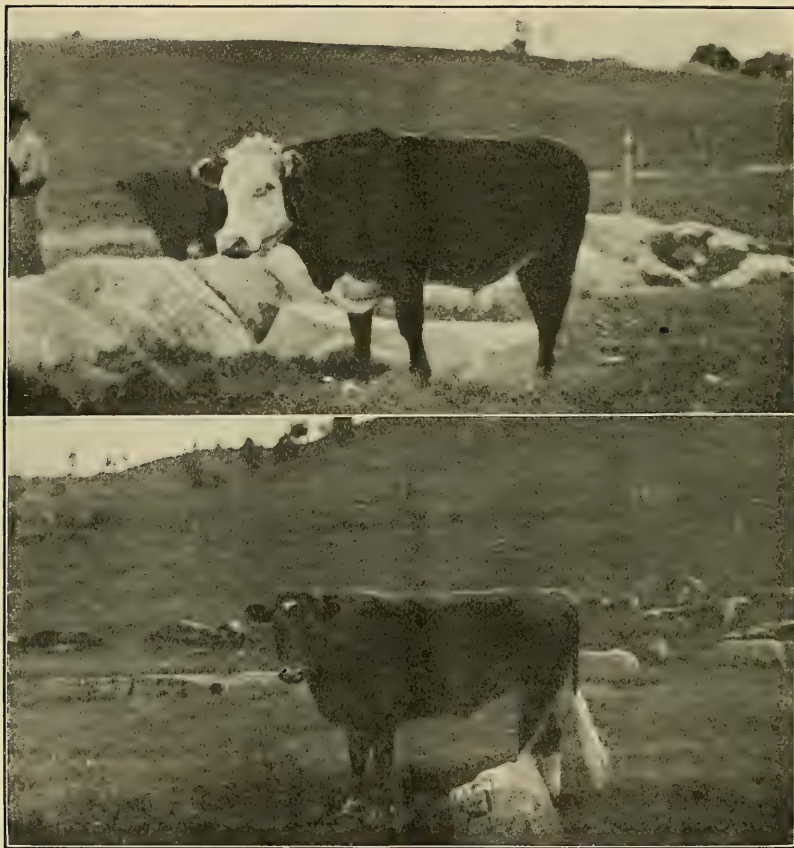


FIG. 3.—Fields too steep and rocky to be plowed, but which make excellent pastures.

extra expense of saving and hauling manure to the pasture fields when the quality of the sod is to be maintained.

It has been shown by the Virginia Agricultural Experiment Station¹ that fairly close grazing will keep a bluegrass sod in better condition than light grazing. The latter practice allows the grass and weeds an opportunity to seed. Cleaning up a field at the close of the grazing period seems to have a similar effect. The trampling of the field by

¹ Carrier, Lyman, and Oakley, R. A. The management of bluegrass pastures. Va. Agr. Exp. Sta. Bul. 204, 18 p., 8 fig. 1914.

stock, unless the land is so wet that it cuts up badly, is also beneficial. The soil of an old turf tends to become too loose. In an investigation carried on in England¹ with a view to discover a method of eradicating moss from old pasture fields, it was found that rolling was the most effective means of overcoming the trouble.

KINDS OF LIVE STOCK RAISED.

Considerable numbers of horses, mules, hogs, and sheep are raised throughout the bluegrass region, but cattle predominate and are here mainly considered. In order to graze profitably, the cattle must be well bred. One of the most serious drawbacks to the grazing industry is the difficulty of obtaining well-bred young cattle. The three leading beef breeds (Shorthorn, Angus, and Hereford) and their crosses



FIG. 4.—Steers which have been fed corn fodder in a pasture. Feeding fodder or hay is an effective means of improving poor spots in a stand of grass.

and grades are well represented, with the Shorthorn breed very much in the majority. Scrub stock will not produce the weight and finish that is required in a steer for export. A good beef calf dropped in the spring should weigh from 350 to 450 pounds the first fall. Twelve months later, as a yearling, he should weigh 700 to 750 pounds; as a 2-year-old he should weigh 1,050 to 1,150 pounds. A steer that will not approximate these weights is marketed for home consumption or kept until he is 4 years old.

WINTERING THE STEERS.

The common practice throughout the bluegrass region is to buy young cattle, commonly spoken of as stockers, in the fall. These are usually kept but one year, although some farmers buy yearlings and

¹ Eradication of moss in pastures. *In Jour. Bd. Agr.* [London], v. 7, 1, p. 39-40. 1900.

keep them two seasons. The financial success of grazing steers depends on (1) the purchase and selling prices, (2) the cost of wintering, and (3) the gains in weight. The yearly gain per steer on good grass is approximately 350 to 400 pounds. This at present prices represents but \$28 to \$32 for the year's keep if the buying and selling prices are the same. With the buying price 1 cent a pound below the selling price, \$7 to \$11 may be added to the above amounts, depending on whether the steers are yearlings or 2-year-olds. It is difficult to figure any profits in the business unless there is at least 1 cent a pound margin in favor of the selling over the cost price to offset the expense of wintering. Even with that margin, the strictest economy must be observed in wintering or there will be nothing left to the credit of the pastures. During recent years there has



FIG. 5.—Two-year-old steers which were wintered on straw, a little corn fodder, and hay.

been little difference between the price for stockers and that for fat cattle. There have also been fewer live cattle exported, so there has not been the advanced price for extra large cattle that formerly prevailed.

The methods of feeding the steers during the winter vary considerably in different localities of the bluegrass region. Nearly all of the graziers let the stock run on the pastures during the winter. Feeding begins in December or January, depending on the season, and continues until the middle of April or the first of May. Forage grown on the farm usually forms the entire ration. In some localities corn fodder, consisting of the unshucked crop, is fed, along with some straw and a little hay. (Figs. 5 and 6.) In other places the farmers shuck the corn and feed the stover, with straw or hay. Usually a little grain is added to the latter ration if the steers become too thin.

The silo is being used more than formerly. (Fig. 7.) The advantages of feeding silage over the old methods of dry feeding are that (1) it avoids the necessity of hauling from the cornfields during wet weather, (2) it enables more stock to be kept on the same acreage of corn, (3) it keeps the animals in better condition, and (4) it clears the entire field early for seeding to wheat. It has often been asserted by experienced graziers that cattle fed silage during the winter do not gain as rapidly on grass as those which were dry fed. Whether this opinion is formed from observation of the gains made the first month or two of the grazing period or from final weights in the fall has never been settled. The evidence given by farmers on this point is very contradictory. With the usual methods of feeding, silage-fed steers



FIG. 6.—Steers like those shown in figure 4 in the condition in which they should appear after a season's grazing.

will weigh more in the spring than they did the previous fall and of course will not make equal gains with the thinner dry-fed cattle when first turned on grass. That more stock can be kept on the same acreage of corn put in a silo than would be possible were the corn allowed to stand in the shock in the field until used is admitted by practically every grazier who has tried both methods. Some claim that twice as many stock can be kept when a silo is used, but the estimate of most farmers is $1\frac{1}{2}$ times the number kept by dry feeding. This is a very important consideration, especially in the mountain sections, where there are sometimes insufficient tillable areas to produce forage to winter the stock which the pastures will carry during the summer. The silo might obviate the necessity of keeping a bluegrass field ungrazed during the summer for winter feed. (Fig. 8.)

GETTING A SOD.

Very little bluegrass has been sown in any of this region except in central Kentucky, where pastures are often plowed and the field cropped for a few years. The customary procedure is to clear additions to the pasture fields and allow the bluegrass to come in itself. (Fig. 9.) It usually takes three or four years by this method to get a fairly good stand of grass. If this is grazed properly, the quality of



FIG. 7.—Silos used for feeding steers during the winter. Silage is being used more generally for this purpose, because more steers can be kept with the same yield of corn ensiled than if fed dry.

the sod will gradually improve for many years. Where the land is level enough to plow and prepare a seed bed, it is possible to permit much more grazing the first two or three years and to get a permanent sod more quickly by seeding a mixture of grasses, such as orchard grass, redtop, red or alsike clover, tall oat-grass, and timothy, along with the bluegrass. Bluegrass and white clover will eventually crowd out most of the other grasses, although orchard grass will persist for many years, thereby adding to the early spring and late fall grazing.

VALUE OF A PASTURE WHEN GRAZED WITH CATTLE.

The grazing on most farms is so intimately connected with other farm operations that it is extremely difficult to separate the returns and say just how much should be credited to the pasture fields. It has



FIG. 8.—A field of grass which is being kept for winter grazing.

been the custom in most farm-economic studies to assign an arbitrary value to the pastures, based on the prevailing prices paid for pasturing stock by the month. There are many fields in the bluegrass region



FIG. 9.—A pasture on cleared woodland. All trees should be cut or deadened and the brush cut and burned.

which are grazed by approximately the same number of cattle every year. As these cattle are purchased one fall by weight and sold the next fall in the same manner, it is possible to get definite figures as to

the yearly gains produced. From this total gain must be deducted the cost of wintering, in order to find the net returns for the pasture. The data secured from a number of farmers in Virginia, West Virginia, and Kentucky are given in Table I. The cost of wintering is based on estimates of the forage fed, which are as accurate as it is possible to obtain from farmers who, as a rule, feed unweighed and unmeasured forage and grain. These pasture fields were among the best in the localities visited (fig. 10) and do not at all represent average conditions for any large area. It does not seem possible to add anything to our knowledge of the value of pastures by averaging with these good grazing lands steep, wooded mountain sides or fields two-thirds of the surface of which is covered with rock.

The values assigned in Table I are 7 cents a pound as the purchase price of stockers, 8 cents as the selling price, \$4 a ton for silage, 60 cents a bushel for corn, \$12 a ton for hay, \$6 a ton for corn stover, and \$4 a ton for straw. It is thought that these represent fair average farm values.

TABLE I.—Results of grazing on 22 bluegrass pastures, consisting of 4,237 acres, with 1,328 head of cattle.

Pasture.		Average data per steer.							Feed during winter.				Cost of wintering.			Yearly returns per acre of pasture.
No.	Area.	Number of steers.	Weight on Oct. 1 (before grazing).	Gain in 1 year.	Yearly gain per acre.	Acreage of pasture.	Price per acre of pasture at the given rate per pound.		Yearly returns per acre.	Corn.	Hay.	Stover.	Straw.	Per steer.	Per acre of pasture.	
							Stoc kers, at 7 cents.	Selling at 8 cents.								
Acres.	Lbs.	Lbs.	Lbs.						Bu.	Tons.	Tons.	Tons.				
1.....	90	501,135	400	222	1.80	\$44.14	\$68.22	\$24.08	400	44	22			\$18.00	\$10.00	\$14.08
2.....	200	501,100	400	100	4.00	19.25	30.00	10.75	400	44	22			18.00	4.50	6.25
3.....	175	451,060	422	108	3.88	19.08	30.49	11.41	360	40	20			18.13	4.66	6.75
4.....	220	501,000	522	119	4.40	15.99	27.67	11.68		125				30.00	6.82	4.46
5.....	68	201,016	390	115	3.40	20.92	33.08	12.16			24	12½		9.70	2.85	9.31
6.....	65	20,706	375	115	3.25	15.23	26.46	11.23		4	15	10		8.90	2.74	8.49
7.....	70	357,750	350	175	2.00	26.25	44.00	17.75		35				12.00	6.00	11.75
8.....	103	306,600	350	102	3.43	12.23	22.13	9.90			32	16		8.53	2.48	7.42
9.....	600	200,650	300	100	3.00	15.17	25.34	10.17			200	100		8.00	2.66	7.51
10.....	90	201,900	500	111	4.50	14.00	24.89	10.89	100	5	20			12.00	2.66	8.23
11.....	80	227,777	350	96	3.63	14.92	24.75	9.83	110		30	25		15.73	4.33	5.50
12.....	265	608,500	300	68	4.41	13.47	20.83	7.36			60	35		8.33	1.88	5.48
13.....	350	150,650	350	150	2.33	19.30	34.29	14.99		30	110	75		8.80	3.77	11.22
14.....	50	197,750	300	114	2.63	19.75	31.92	12.17			20	9		8.21	3.12	9.05
15.....	315	908,550	408	117	3.50	17.32	28.76	11.44		165	80	40		10.00	2.85	8.59
16.....	70	241,100	350	120	2.92	26.40	39.77	13.37	192		24			10.80	3.69	9.68
17.....	775	240,950	425	132	3.23	20.59	34.06	13.47			190	110		6.58	2.04	11.43
18.....	225	751,150	400	133	3.00	26.83	41.33	14.50	1,125	35	50	15		19.40	6.47	8.03
19.....	100	181,050	400	127	5.55	13.23	20.88	7.65	675		25			30.83	5.55	2.10
20.....	50	201,450	300	120	2.50	12.60	24.00	11.40			15	15		7.50	3.00	8.40
21.....	180	609,800	520	173	3.00	22.87	40.00	17.13	1,350	30	60			25.50	8.50	8.63
22.....	96	301,065	450	141	3.20	23.30	37.87	14.57		180		9		11.87	3.71	10.86
Average..	193	60.4	.....	386	121	3.19	19.00	31.41	12.40	.....	.....	.....	.....	12.13	3.80	8.60

¹ Silage (tons).

It will be seen from the data in Table I that the returns varied from \$2.10 per acre for the lowest to \$14.08 for the highest. The average net returns, after allowing a good price for the roughage on the farm, are \$8.60 per acre of pasture. This \$8.60 must pay the taxes, insurance, fencing, and labor of caring for the pastures and stock. The labor bill is small, and so are the other items; but after these are paid there is not much left as interest on the investment. At the present prevailing prices of land the average bluegrass farmer does not make over 3 or 4 per cent on his investment. The average rental price per acre for pasture land in this region is \$3 an acre for fairly good land to \$5 an acre for the best. It is a safe, attractive business to men with considerable capital.



FIG. 10.—One of the best producing pastures in the bluegrass region.

VALUE OF A PASTURE WHEN GRAZED WITH SHEEP.

Sheep grazing is next in importance to cattle grazing over most of the bluegrass region. While the total value of the horses and mules is greatly in excess of that of sheep, most of the former are kept for work purposes.

The income from the sheep is derived principally from the wool and lambs. Ewes that are too old for breeding purposes are also sold for mutton. The lambs are sold at about 5 months of age, when they should weigh about 80 pounds each.

The chief drawbacks to the sheep industry of the bluegrass region are dogs, internal parasites such as stomach worms, nodular disease, etc. Sheep raised in the higher mountain regions of West Virginia and Kentucky are less infested with stomach worms than those in the lower altitudes. On this account there is a considerable demand for breeding ewes that were raised at these higher places.

There is practically no loss from stomach worms before the lambs are 5 months of age. The greatest losses occur in the fall and winter before they are 1 year old. This loss is so great that in many places it is not practicable to raise any breeding ewes, and it also prevents keeping the pastures stocked to their full capacity. Frequent changes of the grazing lands or a larger grazing area for the same number of sheep are the best preventive measures for the trouble.

Table II gives the returns from pasturing sheep on a few fields. It is difficult to obtain definite data in regard to sheep, as few farmers keep them for an entire year without other stock on the same grazing field. The cost of wintering sheep is very low. They graze the pastures all winter and during the cold months are also allowed to graze any small grain, such as wheat or rye, that may be on the farm. Extra feeding must be done when the ground is covered with snow, and also at lambing time, to keep the ewes in good condition. The total outlay for wintering, besides what is obtained from the pastures, seldom exceeds \$1 a head, and usually averages about 75 cents.

TABLE II.—*Pasturing sheep on six pastures in the bluegrass region.*

Pasture.		Number of ewes.	Wool produced.	Number of lambs raised.	Weight of lambs.	Returns.	
No.	Area.					Total (wool at 25 cents and lambs at 7 cents a pound). ¹	Per acre of pasture.
	<i>Acres.</i>		<i>Pounds.</i>		<i>Pounds.</i>		
1.....	30	22	92	34	2,720	\$213.40	\$7.11
2.....	450	200	825	210	15,700	1,305.25	2.90
3.....	220	200	800	300	24,000	1,880.00	8.55
4.....	19	20	88	31	2,325	184.75	9.72
5.....	50	112	560	132	9,900	833.00	12.66
6.....	210	180	810	250	20,000	1,602.50	7.63

¹ The prevailing price for lambs at the time these data were collected was considerably higher than that used in the table.

MAINTAINING THE FERTILITY OF THE SOIL.

There is no system of agriculture that maintains the fertility of the soil better than grazing, especially where the animals are kept continually on the pastures. Some of the best pastures in southwestern Virginia have been grazed for at least 100 years. Many of them have never been plowed. The difficulty in getting a good sod on land that has been cropped with grain for a few years has proved the wisdom of keeping the land permanently in grass. It must be borne in mind that there are striking differences in methods of grazing. Where beef cattle or sheep are grazed, all of the resulting manure is left on the pastures, and the land is further enriched if the animals are given additional feed during the winter. This is usually not the case on dairy farms, where the cattle spend much of the time in yards

or stables. It is often remarked that "the pastures are robbed to keep up the fertility of the plowed fields."

Perhaps one of the greatest sources of loss of fertility from pasture soils results from the poor location of the shade trees and brush. These should always be set on the higher portions of the field, and not along the banks of running streams, as so often is the case. (Fig. 11.) With good grass, the animals do not graze more than one-third of the

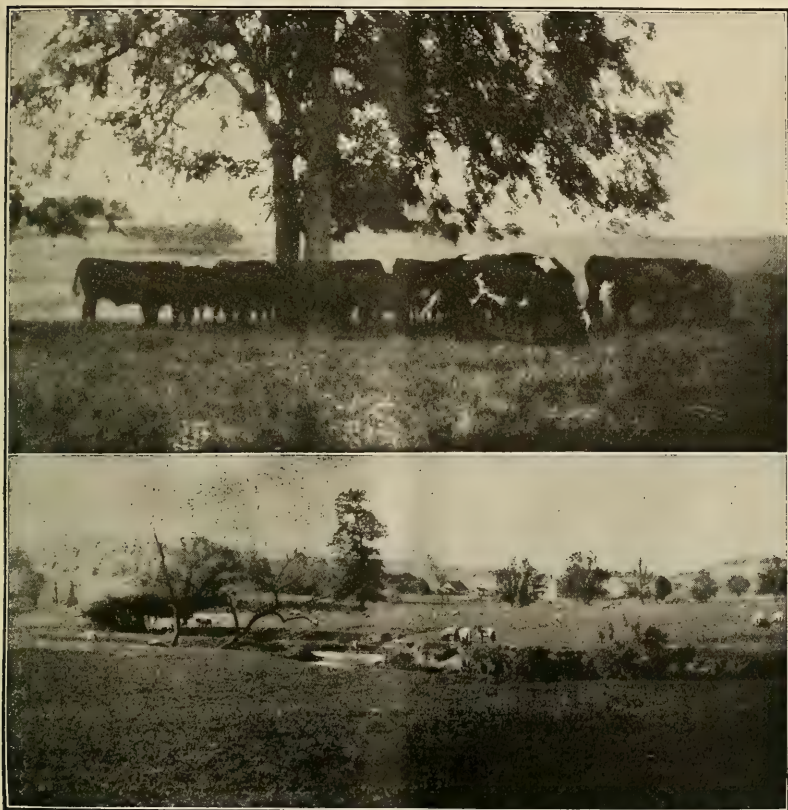


FIG. 11.—Cattle in the shade on an elevated part of a pasture (upper part). Trees should be located in such places and not in the valleys or along running streams, as shown in the lower illustration.

time; the rest of the time is spent lying down or standing in the shade fighting flies. Hence, much of the manure that is made does not get back directly on the land that produced the grass. If the manure produced while the animals are not grazing is deposited on the tops of the hills, its beneficial effects on the grass may be noted for several rods down the hillsides. It is easy to believe that if one-half to two-thirds of the manure is lost from pasture fields and none is added, the crops must gradually deteriorate.

Grazing is not sufficiently remunerative to justify the liberal use of commercial fertilizers, and very little is ever used in the bluegrass region on the pasture lands. In England it is not uncommon to apply basic slag at the rate of 1,000 pounds per acre to permanent grassland. Some farmers in the bluegrass region of Virginia are beginning to use lime and some form of phosphate on their pastures. This improves the stand of grass, but there are no data available to show whether the increase will cover the expense. In the absence of any experimental data, every farmer should experiment on his own fields in a small way. An application of 500 pounds of acid phosphate or bone meal to a half acre in an old pasture will soon show whether it is advisable to use fertilizers. If this quantity makes a marked improvement in the stand of grass, less would probably be beneficial.



FIG. 12.—A bluegrass pasture closely grazed.

THE PROPER RATE TO GRAZE.

Next in importance to maintaining the fertility of the soil in keeping a stand of grass is to stock a pasture properly. A field that is neither mown nor grazed will never form a desirable turf. On the other hand, overgrazing may destroy the plants. There is, however, very little overgrazing in the bluegrass region. If the fields are stocked too heavily, the animals make such poor gains that they are unsalable in the fall. There is greater danger of not keeping sufficient stock. Many of the fields have an appearance similar to neglected lawns. Closely clipped bluegrass on a fertile soil makes such a dense turf that most weeds have difficulty in invading it, but when it is allowed to go to seed the turf is weakened and more open places occur in it. It is impossible to lay down an absolute rule as to the number of animals to allow to the acre. What would be light grazing on one pasture may be overgrazing on another. The fields should be

stocked with a sufficient number of animals so that the grass will not have an opportunity to form seed. (Figs. 12 and 13.)

There is nothing lost by keeping the sod grazed reasonably close. While there is a greater bulk of forage produced when the grass is allowed to mature, the young grass has a much higher nutritive value,¹ which offsets the deficiency in yield.²

CARE OF PASTURES.

Very little labor is necessary to keep a good pasture in first-class condition. All loose stones and rubbish that are removed give that much more space for grass plants to grow. All brush or trees not



FIG. 13.—A bluegrass pasture lightly grazed.

needed for shade or other purposes should be cut or deadened by girdling.

In addition to the above suggestions, all tall-growing weeds should be mown at least once a year, preferably just before they form seed. It is a common practice in central Kentucky and in some other sections of the bluegrass region to mow the weeds. This is done with a mowing machine if the fields are sufficiently smooth; otherwise, by a man with a scythe. The difference in the appearance of fields in localities where weed mowing is practiced and where it is not is very striking. (Figs. 14 and 15.) Mowing will usually hold in check most of the common weeds, such as ragweed, oxeye daisy, thistles, and briars. A few sheep on cattle pastures have been found very efficient in keeping down many troublesome weeds.

¹ Ellett, W. B. The bluegrass of southwest Virginia. Va. Agr. Exp. Sta. Bul. 180, p. 89-96. 1909.

² Ellett, W. B., and Carrier, Lyman. The effect of frequent clipping on total yield and composition of grasses. In Jour. Amer. Soc. Agron., v. 7, no. 2, p. 85-87. 1915.

There has recently been introduced into southwestern Virginia a weed that gives promise of being more damaging to pastures than anything that has heretofore appeared. It is the field hawkweed (*Hieracium pratense*), a low-growing plant, somewhat resembling narrow-leaved plantain, but the stems and leaves are hairy. It spreads by underground stems and forms a dense mat, which crowds out most other plants. The flowers are bright yellow, borne on naked, upright stalks 8 to 20 inches high. This weed, along with other closely related species, has already damaged the pastures of New York and New England greatly. It could now be eradicated from

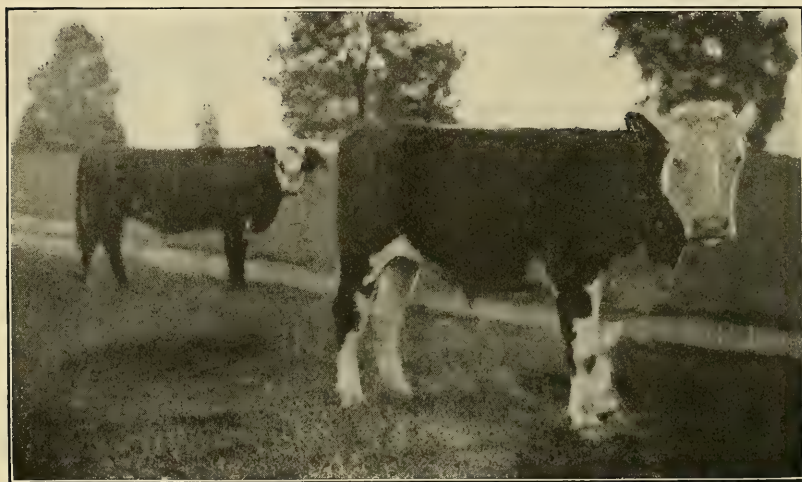


FIG. 14.—A pasture where weed mowing is practiced.

the bluegrass region if the farmers would attack it before it is distributed farther.

Hawkweed may be destroyed by chopping it out with a hoe or mattock. If this method is used, care should be exercised to get all the rootstocks in the upper inch or two of the soil and destroy them. Another method, which seems to be about the best that can be suggested at the present time, is to spray the plants on a clear day with a solution of ordinary salt. Three pounds of salt to 1 gallon of water is the proportion that has given the best results. Every patch treated should be inspected occasionally, as it may require two or three sprayings to entirely kill the hawkweed. If the weed is in small patches, which is the way it usually starts, a man equipped with a knapsack sprayer can cover a large area in a day. The spraying may be done at any time, but it is much easier to find the plant when it is in bloom. The showy yellow flowers are very conspicuous and may be seen and recognized for a considerable distance.

THE SUPPLY OF STOCKERS.

One of the chief difficulties of the grazing farmer in the bluegrass region is the lack of stockers. A few cows are kept on nearly every farm, but they produce but a small number of the calves that are needed. The reason that so few calves are raised on the bluegrass lands is because it is more profitable to graze a steer than to keep a cow an entire year just for her calf. Dairying does not fit in well in the agricultural scheme of the region. There is not sufficient level land in most localities to produce the forage necessary to keep a dairy herd in winter, and any admixture of dairy blood renders 1,500-pound 3-year-old steers impossible. A few graziers have tried buying yearling heifers, keeping them until they get one calf and then selling the mothers.

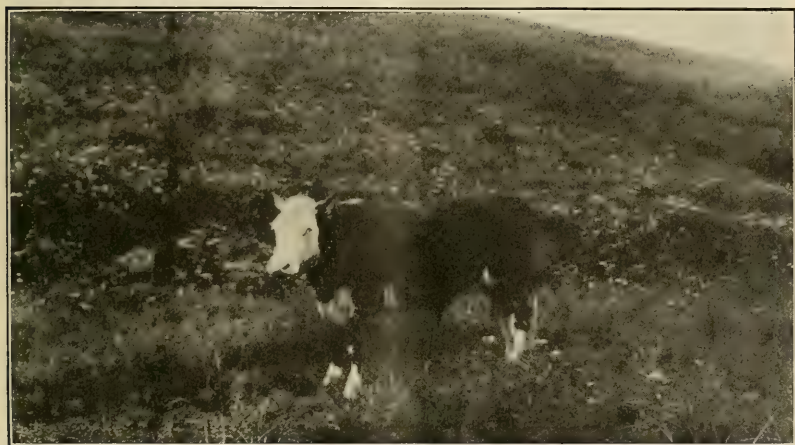


FIG. 15.—A pasture where weeds have not been mowed.

By this method they get not only the calf but an increase in the weight of the heifer. Some stockers are purchased in Chicago or Cincinnati, and a few come from Canada, but most of them are raised in the mountains of North Carolina, Tennessee, West Virginia, and eastern Kentucky by men who keep but a few cows, which range at will. These calves are purchased by local cattle dealers, who sell to the grazing farmers. The quality of the stock is maintained largely because the best graziers have distributed pure-bred bulls for free service wherever they are most needed. (Fig. 16.)

There should be a fairly profitable business on the cheaper lands of the Blue Ridge and in the Piedmont section in raising beef-bred calves for the bluegrass graziers. This will necessitate, however, the keeping of a much better grade of beef cattle than is usual. A good beef-bred calf will sell readily when 6 months old for \$25 to \$30. If

the dam is of a milking strain, considerable additional revenue may be obtained from the sale of dairy products after the calf is sold. This suggestion is made not that this type of farming is more profit-

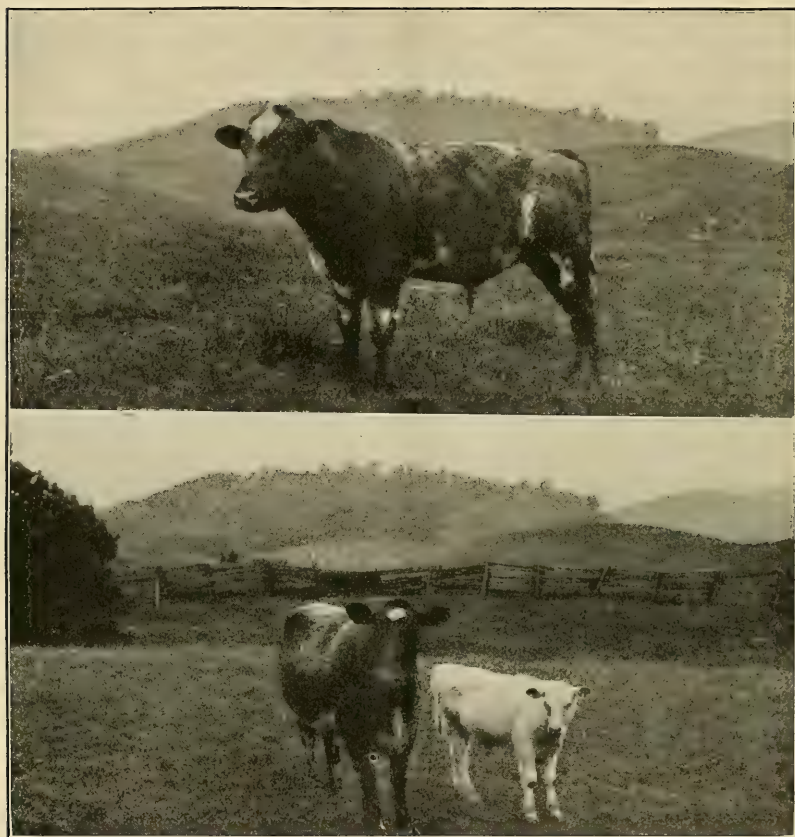


FIG. 16.—Polled Durham breeding stock in Tazewell County, Va. The quality of the grazing stock is maintained by the distribution of pure-bred bulls in the localities where the stockers are produced.

able than dairying, for it is not, but because it requires far less efficient labor than dairying and offers a means of utilizing a vast acreage of gullied hills which at present is waste land.

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BULLETIN No. 398

Contribution from the Bureau of Plant Industry
WM. A. TAYLOR, Chief



Washington, D. C.

October 12, 1916

CEREAL EXPERIMENTS AT THE JUDITH BASIN SUBSTATION, MOCCASIN, MONT.

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(In cooperation with the Montana Agricultural Experiment Station.)

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INTRODUCTION.

Experiments with cereals have been conducted cooperatively since 1908 at the Judith Basin substation,¹ Moccasin, Mont., by the Office of Cereal Investigations of the Bureau of Plant Industry and the Montana Agricultural Experiment Station. The memorandum of understanding between the two parties specifies that—

The objects of these cooperative investigations shall be (1) to improve the cereals of the northern Plains region by introducing better varieties than those now grown, especially with regard to drought resistance, yield, quality, earliness, etc., and (2) to conduct such other experiments as may seem advisable for the accomplishment of the greatest possible good to the dry-land interests of the State.

This bulletin presents briefly the results of these investigations, together with such conclusions as they seem to warrant. All experiments here reported have been conducted under dry-land conditions.

¹ The Judith Basin substation was established in 1908 by the Montana Agricultural Experiment Station in cooperation with the Bureau of Plant Industry. Prof. F. B. Linfield has been director of the State station since the substation was started. Prof. Alfred Atkinson, head of the agronomy department at the State station, has had direct charge of the substation for the State. Mr. J. M. Stephens has been superintendent of the substation since its establishment. Mr. E. L. Adams was in charge of the experiments with cereals from 1909 to 1912. On his transfer to another station in May of the latter year, the writer of this bulletin was appointed agent of the Office of Cereal Investigations to take charge of the cooperative cereal work and on October 1, 1912, was appointed scientific assistant.

DESCRIPTION OF THE JUDITH BASIN.

The following rather detailed description of the Judith Basin and the conditions obtaining there allows comparison with other parts of the State of Montana where it is believed that the substation results are applicable.

TOPOGRAPHY.

The Judith Basin is an area of nearly 2,000,000 acres of tillable bench land lying in the western half of Fergus County, Mont. The basin, so called because it is nearly surrounded by mountains, is about 75 miles from east to west and 50 miles from north to south. The Little Belt Mountains form the southern and western boundaries. The Highwood Mountains and the Bad Lands, or breaks, of the Missouri River lie to the north. The North and South Moccasin, the Judith, and the Snowy Mountains form the eastern boundary. The basin is drained by the Judith River and its tributaries. Part of the land along the river and creek bottoms can be irrigated, but by far the larger part of the district is classed as dry land.

Until a few years ago the Judith Basin was a range country. The only land farmed was along the river and creek bottoms, while the bench lands were used to pasture great herds of cattle and sheep. Within the last 10 years practically all the tillable land in the Judith Basin has been brought under cultivation. Winter wheat is raised almost exclusively, although a few of the farmers are gradually working into a more diversified system of farming.

SOILS.

The soils of the Judith Basin are rather variable. The surface soil is a dark, heavy clay loam of limestone origin, which varies in depth from a few inches to 3 feet. The soil when wet becomes very sticky, and because of its adhesive character can be plowed only with a disk plow. Analysis of the soil shows that apparently it is quite rich in available plant food. The subsoil to a depth of 30 feet is composed of limestone gravel closely cemented together and is of such character as will not allow the storage of water or the development of roots.

The composition of the soil at the substation, as determined by mechanical analysis, is shown in Table I. The stickiness of the soil is due largely to its high percentage of silt and clay, 40.7 and 24.3 per cent, respectively, in the surface foot.

TABLE I.—Composition of the soil at the Judith Basin substation, Moccasin, Mont., as determined by mechanical analysis.

Constituents.	First foot.	Second foot.	Constituents.	First foot.	Second foot.
	<i>Per cent.</i>	<i>Per cent.</i>		<i>Per cent.</i>	<i>Per cent.</i>
Fine gravel.....	0.9	1.1	Very fine sand.....	13.4	11.6
Coarse sand.....	2.7	2.3	Silt.....	40.7	33.3
Medium sand.....	4.4	3.2	Clay.....	24.3	38.1
Fine sand.....	13.3	10.4			

NATIVE GRASSES.

In the original state the bench lands of the Judith Basin are covered with grass. The most important native grass is grama grass (*Bouteloua oligostachya*). Buffalo grass (*Bulbuls dactyloides*), western wheat-grass (*Agropyron smithii*, formerly *A. occidentale*), slender wheat-grass (*Agropyron tenerum*), and needle grass (*Stipa comata* and *S. viridula*) are also found, but are not as abundant as the grama grass. The grasses on the bench land make very good pasture, but seldom grow tall enough to be cut for hay.

CLIMATE.

Before discussing crop yields or attempting to draw any conclusions it is necessary to have in mind the climatic factors affecting crop growth. The most important of these factors are (1) seasonal and annual rainfall, (2) the seasonal evaporation, and (3) temperature, with special reference to the length of the growing season as limited by the spring and fall frosts. With the exception of the rainfall records from 1898 to 1908, all data on these factors here presented have been obtained at the substation at Moccasin.

PRECIPITATION.

Table II gives the annual and average precipitation by months in the vicinity of Moccasin for the 18 years from 1898 to 1915, inclusive. Previous to 1909 the records were taken at Utica, 7 miles southwest of the substation. Since that time they have been taken at the substation by the Biophysical Laboratory of the Bureau of Plant Industry. The average annual precipitation for 18 years (Table II) is 16.66 inches. During this time the maximum precipitation in any one year was 23.76 inches (1909), and the minimum, 10.42 inches (1900).

The peculiar soil conditions existing at Moccasin and more or less throughout the Judith Basin make it nearly impossible to store any appreciable amount of moisture in the soil. The seasonal distribution of the rainfall, therefore, is of great importance. The growing season for spring grains at Moccasin extends from about April 1 to August 10. Since the precipitation that falls after the 1st of August has little effect on the yields of the crops, the growing season is considered as extending from April 1 to July 31. The average precipitation in this 4-month period during 18 years is 9.41 inches, or 56 per cent of the average annual precipitation.

TABLE II.—*Monthly, seasonal, and annual precipitation (in inches) in the vicinity of Moccasin, Mont., during the 18 years from 1898 to 1915, inclusive.*¹

[Data from the records of the United States Weather Bureau and of the Biophysical Laboratory of the Bureau of Plant Industry.]

Year.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Seasonal.	Total.
1898.....	0.70	0.27	1.91	1.12	5.87	5.80	3.16	0.67	0.47	1.25	1.14	0.59	15.95	22.95
1899.....	1.69	.38	.92	2.29	3.33	1.22	2.57	1.31	.28	1.15	.11	.88	9.41	16.13
1900.....	.45	.35	.21	2.85	1.04	.44	.70	2.20	.82	.86	.29	.21	5.03	10.42
1901.....	.40	.20	.57	1.65	3.82	3.97	1.97	.90	2.42	1.39	² T	3.22	11.41	20.51
1902.....	.14	.24	.45	1.12	1.41	3.28	1.84	.67	.32	.18	2.04	.25	7.65	11.94
1903.....	.50	.24	1.11	2.29	1.82	2.81	2.57	.81	2.42	.05	.44	.65	9.49	15.71
1904.....	.18	.22	.79	1.14	1.94	1.73	3.25	.42	.12	.54	.50	.24	8.06	11.07
1905.....	.19	.16	.62	.75	1.97	2.82	3.19	.27	.83	.39	.50	T	8.73	11.69
1906.....	.55	.63	.43	.16	2.61	2.66	.93	2.00	.99	.70	.42	.68	6.56	12.76
1907.....	1.34	.08	.61	.43	3.21	6.75	3.51	1.47	.73	.20	T	T	13.90	18.33
1908.....	.55	.49	.98	.61	7.31	2.45	.20	1.18	1.41	6.27	T	.22	10.57	21.67
1909.....	.90	.08	1.22	1.03	1.34	5.97	2.54	4.21	4.47	.49	.30	1.21	10.88	23.76
1910.....	.09	.74	.10	1.31	2.40	1.69	1.10	2.02	2.54	1.36	1.26	.48	6.50	15.09
1911.....	.58	.55	.54	1.66	2.98	2.55	.50	6.34	1.37	1.94	1.76	.68	7.69	21.45
1912.....	.88	.60	.81	1.43	3.94	.64	1.92	1.27	1.63	1.68	.14	.06	7.93	15.00
1913.....	.89	.09	.20	.79	2.64	4.77	1.12	.51	1.01	1.63	.93	.38	9.32	14.96
1914.....	.47	1.35	1.12	1.19	2.91	4.64	.64	.65	1.11	.74	.64	.21	9.38	15.67
1915.....	.76	.08	2.69	1.43	2.12	3.97	3.54	.92	2.65	.85	1.01	.66	11.06	20.63
Average....	.62	.38	.85	1.29	2.93	3.23	1.96	1.55	1.42	1.20	.64	.59	9.41	16.66
Maximum...	1.69	1.35	2.69	2.85	7.31	6.75	3.54	6.34	4.47	6.27	2.04	3.22	15.95	23.76
Minimum....	.09	.08	.10	.16	1.04	.44	.20	.27	.12	.05	T	T	5.03	10.42

¹ Precipitation records previous to 1909 were taken at Utica, Mont., 7 miles southwest of the substation; in 1909 and since they were taken at the station.² T=trace.

Table III gives the average monthly, annual, and seasonal precipitation at the Judith Basin substation in the nine years from 1907 to 1915, inclusive, the years during which experiments have been conducted at Moccasin. This table has been compiled from the

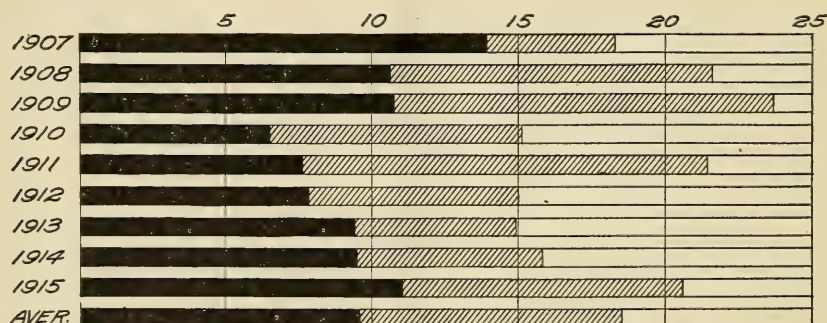


FIG. 1.—Diagram showing the annual and seasonal precipitation, in inches, at the Judith Basin substation, Moccasin, Mont., for nine years, 1907 to 1915, inclusive. Solid bars show the seasonal precipitation, while the total length of the bars shows the annual precipitation.

monthly and annual records given in Table II. The data for 1907 and 1908 are from the Weather Bureau records taken at Utica, 7 miles southwest of the station. The data for the remaining years are from the records of the Biophysical Laboratory of the Bureau of Plant Industry, taken at Moccasin. Figure 1 presents this data for each year in graphic form.

TABLE III.—Average monthly, seasonal, and annual precipitation (in inches) at Moccasin, Mont., during the nine years from 1907 to 1915, inclusive.

[Data from the records of the United States Weather Bureau and of the Biophysical Laboratory of the Bureau of Plant Industry.]

Nine years.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Seasonal.	Total.
Average.....	0.72	0.45	0.92	1.09	3.20	3.72	1.67	2.06	1.86	1.68	0.67	0.43	9.69	18.51
Maximum.....	1.34	1.35	2.69	1.43	7.31	6.75	3.54	6.34	4.47	6.27	1.76	1.21	13.90	23.76
Minimum.....	.09	.08	.10	.43	1.34	.64	.20	.51	.73	.20	¹ T	T	6.50	14.96

¹ T=trace.

Since winter wheat usually is sown during August and September the record of seasonal precipitation for winter wheat should include these months. Table IV shows the annual and average precipitation in the calendar year and in the crop year for winter grains, the precipitation during the growing season for winter wheat, and the seasonal precipitation for spring small grains (Apr. 1 to July 31) in the eight years from 1908 to 1915, inclusive. In the crop year for winter wheat the figures are for the 12 months ended July 31 of the year indicated; that is, they show the precipitation affecting the crop of winter wheat harvested that year. In the same way, the precipitation during the growing season for winter wheat includes the three months (August to October) just preceding and following the seeding season and the four months (April to July) of the following spring and summer, thus covering the entire growth period of the crop. The winter precipitation (November to March, inclusive) may be easily determined by subtracting the figures for the growing season from those immediately preceding them in Table IV.

TABLE IV.—Annual and average precipitation (in inches) during the calendar year and in the crop year for winter grains and seasonal precipitation for spring grains at the Judith Basin substation in the eight years from 1908 to 1915, inclusive.

Period.	1908	1909	1910	1911	1912	1913	1914	1915	Average.
Annual.....	21.67	23.76	15.09	21.45	15.00	14.96	15.67	20.68	18.53
Crop year for winter grains (Aug. 1 to July 31). ¹	14.99	22.16	18.11	17.02	22.31	15.28	16.78	17.94	18.07
Growing periods for winter grains. ²	12.97	19.74	15.67	13.61	17.58	13.90	12.53	13.56	14.94
Seasonal, for spring grains (Apr. 1 to July 31).....	10.57	10.88	6.50	7.69	7.93	9.32	9.38	11.06	9.16

¹ The figures in each column are for the 12 months ended July 31 of the year indicated.² The figures in each column are for August to October of the preceding year (precipitation affecting fall growth) and April to July of the year indicated (precipitation affecting spring and summer growth).

To permit comparison of the precipitation at Moccasin with that in other portions of the State, the average annual precipitation at 25 different points in Montana, including Moccasin, is given in Table V. These data were obtained from the records of the United States Weather Bureau as published by the Montana Agricultural Experi-

ment Station.¹ In nearly all cases the average is for 16 years, 1898–1913, inclusive.

Table V shows that the precipitation at Moccasin is a little higher than in eastern Montana, but about the same as that of the central and western parts of the State. The locations of the stations for which data are given are shown in figure 2.

TABLE V.—Average precipitation at 25 stations in Montana, including Moccasin, for the years indicated.

[Data from the records of the United States Weather Bureau.]

Station.	Period.	Average.
Eastern Montana:		<i>Inches.</i>
Ekalaka.....	16 years (1898 to 1913)	13.32
Glendive.....	do.....	15.50
Poplar.....	do.....	14.12
Glasgow.....	do.....	13.95
Miles City.....	do.....	14.07
Forsyth.....	10 years (1904 to 1913)	13.32
Crow Agency.....	16 years (1898 to 1913)	15.37
Billings.....	9 years (1905 to 1913)	14.15
Central Montana:		
Chinook.....	16 years (1898 to 1913).....	12.39
Havre.....	do.....	12.96
Fort Benton.....	15 years (1898 to 1912).....	13.71
Great Falls.....	16 years (1898 to 1913).....	15.86
Lewistown.....	do.....	19.77
Red Lodge.....	do.....	19.76
Livingston.....	15 years (1896 to 1910).....	14.33
Bozeman.....	16 years (1898 to 1913).....	18.28
Western Montana:		
Helena.....	16 years (1898 to 1913).....	14.06
Adel.....	do.....	21.35
Augusta.....	do.....	16.50
Cut Bank.....	do.....	14.76
Kalispell.....	do.....	15.32
Missoula.....	do.....	15.31
Butte.....	do.....	14.65
Dillon.....	do.....	17.86

SUMMARY.

Average at 8 stations:	
In eastern Montana.....	14.23
In central Montana.....	15.88
In western Montana.....	16.22
Average at all stations.....	15.44
Moccasin, 16-year period (1898 to 1913).....	16.46

EVAPORATION.

Of the climatic factors that influence crop growth, evaporation is probably next in importance to seasonal precipitation. Evaporation records have been taken at Moccasin since 1909. The evaporation is determined from a free water surface, the method being the one usually employed where the Biophysical Laboratory of the Bureau of Plant Industry is cooperating.²

Records are taken during six months, April to September, inclusive. In Table VI the evaporation and precipitation in these months are

¹ Burke, Edmund, and Pinckney, R. M. Temperature records 1898–1913. An appendix to report on Montana climate. Mont. Agr. Exp. Sta. Bul. 99, p. 68–143. 1914.

² Briggs, L. J., and Belz, J. O. Dry farming in relation to rainfall and evaporation. U. S. Dept. Agr., Bur. Plant Indus. Bul. 188, p. 16–20. 1910.

given for the seven years from 1909 to 1915, inclusive. This table also gives the total and average precipitation and evaporation in this period, with the ratio of the total precipitation to total evaporation.

TABLE VI.—*Monthly precipitation and evaporation (in inches) from a free water surface at the Judith Basin substation, Moccasin, Mont., from April to September of each year from 1909 to 1915, inclusive.*

[Data from the records of the Biophysical Laboratory of the Bureau of Plant Industry.]

Year.	April.		May.		June.		July.		August.		September.		Total.		Ratio.
	Precipitation.	Evaporation.	Precipitation.	Evaporation.	Precipitation.	Evaporation.	Precipitation.	Evaporation.	Precipitation.	Evaporation.	Precipitation.	Evaporation.	Precipitation.	Evaporation.	
1909....	1.03	3.00	1.34	4.66	5.99	6.00	2.54	7.22	4.21	7.06	4.47	4.67	19.58	32.61	1:1.6
1910....	1.31	5.18	2.40	5.61	1.69	7.21	1.10	8.28	2.02	7.38	2.54	6.48	11.06	40.14	1:3.6
1911....	1.66	4.10	2.98	5.94	2.55	5.13	.50	7.31	6.34	6.35	1.37	3.41	15.40	32.22	1:2.1
1912....	1.43	2.62	3.94	4.14	.64	6.39	1.92	5.97	1.27	6.23	1.63	3.42	10.83	28.77	1:2.6
1913....	.79	3.89	2.64	4.23	4.77	4.90	1.12	6.37	.51	7.35	1.01	5.83	10.84	32.58	1:3.0
1914....	1.19	3.21	2.91	4.85	4.64	4.43	.64	7.45	.65	7.24	1.11	5.10	11.14	32.27	1:2.8
1915....	1.43	4.70	2.12	4.61	3.97	4.35	3.54	4.89	.92	6.51	2.65	3.43	14.63	28.49	1:1.9
Average	1.28	3.81	2.92	4.86	3.04	5.49	1.82	6.78	2.27	6.87	2.11	4.62	13.35	32.44	1:2.4

The greatest evaporation in any one year, as shown in Table VI, was 40.14 inches (1910). While the seasonal precipitation (Apr. 1 to Sept. 30) in 1910 was not quite as low as in some of the other



Fig. 2.—Map of Montana, showing the average annual precipitation (in inches) at the Judith Basin substation and at 24 other points in the State. These averages, for the most part, are for 16 years (1895 to 1915, inclusive).

years, the ratio between the precipitation and evaporation was wider than in any other year. The average ratio for the seven years is 1:2.4. A comparison of this ratio with the ratios for the different years gives a very fair basis for judging the seasonal conditions under which the experiments for each year were conducted.

WIND.

Measurements of the wind velocity have been taken since 1910 at the Judith Basin substation by the Biophysical Laboratory of the Bureau of Plant Industry. The records are taken during six months, April to September, inclusive. The anemometer stands near the evaporation tank, at a height of about 2 feet above the surface of the ground. Table VII gives the average wind velocity from April to September in the six years from 1910 to 1915, inclusive.

TABLE VII.—Average wind velocity (in miles per hour) at the Judith Basin substation, Moccasin, Mont., by months, from April to September of each year from 1910 to 1915, inclusive.

[Data from the records of the Biophysical Laboratory of the Bureau of Plant Industry.]

Year.	Apr.	May.	June.	July.	Aug.	Sept.	Average.
1910.....	9.0	6.8	6.3	5.9	6.0	4.0	6.33
1911.....	7.8	8.0	5.4	5.9	5.9	5.3	6.38
1912.....	6.6	7.6	5.7	5.1	6.4	6.7	6.35
1913.....	8.7	6.5	5.3	5.0	5.4	6.5	6.23
1914.....	6.3	7.5	6.4	5.5	6.0	7.2	6.48
1915.....	7.6	7.5	6.6	5.1	4.9	5.9	6.26
Average.....	7.7	7.3	6.0	5.4	5.8	5.9	6.35

Table VII shows that April has the highest average wind velocity, 7.7 miles per hour. The average wind velocity decreases through May, June, and July, but increases again slightly in August and September. The 6-year average velocity in the six months is 6.35 miles per hour.

TEMPERATURE.

Table VIII gives the mean, maximum, and minimum temperatures at the Judith Basin substation by months from April to September of each year from 1909 to 1915, inclusive. The highest average mean temperatures occur in July and August, 63° F., and the highest average maximum in August, 77° F. Temperatures as high as 95° F. are rare in the Judith Basin. When hot weather occurs it lasts for only a short time. Hot, drying winds are uncommon. In only one year since the station was started have hot winds done any damage to the growing crops.

TABLE VIII.—Mean, maximum, and minimum temperatures (°F.) at the Judith Basin substation, Moccasin, Mont., by months, from April to September of each year from 1909 to 1915, inclusive.

[Data from the records of the Biophysical Laboratory of the Bureau of Plant Industry.]

Year.	April.			May.			June.			July.			August.			September.			Seasonal mean.
	Mean.	Maximum.	Minimum.	Mean.	Maximum.	Minimum.	Mean.	Maximum.	Minimum.	Mean.	Maximum.	Minimum.	Mean.	Maximum.	Minimum.	Mean.	Maximum.	Minimum.	
1909.....	35	44	25	49	60	38	58	68	47	63	74	50	65	78	50	59	68	49	55
1910.....	49	65	34	51	62	41	60	74	47	68	82	53	62	75	47	53	63	41	57
1911.....	38	51	26	48	59	37	60	71	47	62	77	45	58	70	47	50	62	38	52
1912.....	43	55	31	50	60	37	61	74	45	61	75	47	62	76	47	48	60	35	54
1913.....	43	55	31	49	63	38	60	73	48	62	76	48	65	81	49	55	72	40	56
1914.....	42	56	29	51	65	37	57	69	45	68	83	51	62	77	45	56	71	40	56
1915.....	50	62	37	49	59	38	52	62	42	58	69	46	66	81	51	49	59	38	54
Average....	43	55	30	49	61	38	58	70	46	63	76	49	63	77	48	53	65	40	55

Table IX gives the dates of the last spring and first fall frosts and the number of days in the frost-free period in each year from 1909 to 1915, inclusive.

The longest frost-free period was 150 days, in 1909, and the shortest 82 days, in 1910. The latest frost in the spring was on June 4, in 1911. The average date of the last frost in the spring is May 20. The earliest frost in the fall in the seven years occurred on August 23, in 1910. The average date of the first frost in the fall is September 13. The average length of the frost-free period in the seven years is 116 days.

TABLE IX.—*Dates of killing frosts, the last in spring and first in fall, with length of frost-free period in each year from 1909 to 1915, inclusive, at the Judith Basin substation, Moccasin, Mont.*

[Data from the records of the Biophysical Laboratory of the Bureau of Plant Industry.]

Year.	Last in spring.	First in fall.	Frost-free period.	Year.	Last in spring.	First in fall.	Frost-free period.
			<i>Days.</i>				<i>Days.</i>
1909.....	May 15	Oct. 12	150	1914.....	May 12	Sept. 12	123
1910.....	June 2	Aug. 23	82	1915.....	May 16	Sept. 11	118
1911.....	June 4	Sept. 15	103				
1912.....	May 12	Sept. 15	126	Average.....	May 20	Sept. 13	116
1913.....	May 19	Sept. 9	112				

THE JUDITH BASIN SUBSTATION.

LOCATION.

The Judith Basin substation is located 2 miles west of the town of Moccasin, in Fergus County, Mont., in the central part of the Judith Basin and about the geographical center of the State. The latitude is about 47° N., and the longitude 109° 45' W. The substation farm is section 16, township 15 north, range 14 east. A branch of the Great Northern Railway from Great Falls to Billings passes through one corner of the station section.

DESCRIPTION.

The station farm consists of 640 acres. One corner of the farm is creek bottom and the remainder is level, tillable bench land. About 320 acres are under cultivation and the rest is used for pasture. The elevation at the substation is 4,300 feet. Figure 3 gives a view of the substation buildings in 1915.

It is believed that the results obtained at Moccasin are applicable to the whole of the Judith Basin and in a general way to the 20,000,000 acres of dry land throughout the State, where the annual rainfall and its distribution are the chief factors limiting crop growth.

SCOPE OF THE EXPERIMENTS.

The experiments with cereals may be divided into two groups, plat tests and nursery tests. A general view of the plat and nursery is shown in figure 4. The plat experiments consist of varietal,

date-of-seeding, and rate-of-seeding tests of winter and spring wheat, and spring oats, barley, and flax. In different years the number of varieties under trial has varied from 75 to 125. The number of plats in the date-of-seeding and rate-of-seeding tests has ranged from 40 to 60, so that the total number of experiments has varied from 115 to 185.

The nursery work at Moccasin covers two general lines: (1) The introduction and testing of new varieties, and (2) experiments in the improvement of cereals. New varieties are usually tested in nursery rows before being grown in plats. This makes possible the testing of a large number of varieties with much less time and labor than would be necessary in larger plats.

The effort in the improvement work has been to select individual heads representing desirable types. These selections usually are made from the varieties that have given the best results in the plat



FIG. 3.—Buildings at the Judith Basin substation, Moccasin, Mont., in 1915. (From a photograph lent by the Office of Exhibits, U. S. Department of Agriculture.)

tests. These selections are multiplied and tested for yield and other desirable characters, such as length and stiffness of straw and freedom from shattering. The poor selections are discarded and the promising ones increased.

The number of rows has varied from 256 in 1909 to 840 in 1911. Most of these are devoted to the improvement work. Since 1911 the number of rows has been reduced as the poor selections are discarded and the promising ones increased.

EXPERIMENTAL METHODS.

That portion of the substation farm used for plat work is divided into blocks 132 feet wide and 617 feet long, which are separated by roads 1 rod wide. These blocks may be divided into tenth-acre, twentieth-acre, or fiftieth-acre plats, each 132 feet, or 8 rods, long.

PLAT EXPERIMENTS.

SIZE OF PLATS.

All of the varieties in 1908 and 1909 and nearly all in 1910 were grown on tenth-acre plats. In 1911 and 1912, because of the short-

age of land, all crops except winter wheat were grown on twentieth-acre plats. The tenth-acre plats are 2 rods wide and 8 rods long, with alleys $3\frac{1}{2}$ feet wide between the plats and roads 1 rod wide between the blocks or series of plats. The twentieth-acre plats were 1 rod wide and 8 rods long, with 20-inch alleys.

In 1913 some of the winter wheat varieties were grown on acre plats. These plats were 8 rods wide and 20 rods long. The spring-wheat varieties were grown in fiftieth-acre plats, and the rest of the spring cereals in tenth-acre plats. In 1914 and 1915, part of the winter-wheat varieties were grown in acre plats and the spring cereals in fiftieth-acre plats. The fiftieth-acre plats are 6 feet wide and 8 rods long, with 18-inch alleys. This plat is actually one fifty-fifth of an acre in area, but as some moisture and plant food are drawn from the alleys, it seems fair to consider them as fiftieth-acre plats in computing acre yields.



FIG. 4.—General view of the cereal experiment plats at the Judith Basin substation, Moccasin, Mont., 1910.

REPLICATION OF PLATS.

From 1908 until 1913 all varieties were grown in single tenth-acre or twentieth-acre plats. In every year except 1908 check plats of a standard variety were grown. In 1913 the spring-wheat varieties were grown in replicated fiftieth-acre plats, and in 1914 and 1915 all crops except the winter-wheat varieties in acre plats were grown in this way. A 6-foot drill is used and one drill width across the series (8 rods) covers one-fiftieth of an acre. As stated before, these plats are really one fifty-fifth of an acre in area, but in computing acre yields they are considered as one-fiftieth of an acre. In the system of plat replication in use at the Judith Basin substation five plats of each variety are grown. These plats are distributed throughout the space devoted to the test. In computing the yields of the varieties grown in replicated plats the average yield of the five fiftieth-acre plats of any one variety is obtained and the acre yield then computed.

PREPARATION OF THE LAND.

With few exceptions all the varietal tests of cereals have been conducted on fallow ground. In 1908 the crops were sown on sod

broken in 1907. In 1910 it was necessary to grow the barley varieties on land that had been cropped to barley the previous year. In 1911 and 1912 the flax varieties were sown on ground that had produced a crop the year previous. In all other cases the varietal experiments were conducted on fallow ground. A good job of breaking is shown in figure 5.

Where the land was continuously cropped, the plowing was done in the spring and a good seed bed prepared before sowing. The fallow ground was usually plowed in June or July, after weeds and



FIG. 5.—Sod land in the Judith Basin broken with a moldboard plow. The plow should have been followed by a heavy roller to flatten the furrow slice and bring it in contact with the moist subsoil.

volunteer grain were well started. Plowing was done with a disk plow to a depth of 7 to 8 inches. It was found that if the land was worked down smooth after plowing there was likely to be considerable blowing of the soil during the winter; consequently, it has been the custom to leave the land rough until spring, when it is worked down with the disk and spike-tooth harrows to form a good seed bed.

In the preparation of the land an effort has been made to follow actual farm practices as closely as possible. In some cases it has been necessary to do some cultivating and hand weeding in order to keep the land uniform, but on the whole the plats have not received any more cultivation than would be given under good farming conditions.

TREATMENT OF CROPS.

The seeding has been done with an 8-foot double-disk and a 6-foot single-disk drill. On each drill the spouts were 6 inches apart. After seeding no cultivation has been given the plats. In some years it was necessary to cultivate the alleys and roads in order to kill the weeds. In the 18-inch alleys between the fiftieth-acre plats the weeds are pulled by hand, and no cultivation is necessary.

Harvesting is done with a binder. The grain is shocked on the plats and remains there until it is thrashed. The thrashing is done with a small thrasher with a 26-inch cylinder. Since the varieties have been grown in the replicated plats, one plat of each variety has been carefully rogued and the crop from this plat thrashed in the small nursery thrasher. By this method it is possible to avoid the mixture that takes place in the larger thrasher and thus obtain pure seed of each variety.

CROP RECORDS.

The first notes taken after sowing are on the date of emergence. After this, notes are taken on the stand of the different varieties. Since all the varieties of any one cereal are seeded at the same rate and on the same date all stands are usually uniform, but any differences are noted. Any disease that may appear is noted, as is also the percentage of lodging. Records are kept of the dates of heading, ripening, and cutting of each variety.

NURSERY EXPERIMENTS.

The new varieties tested in the nursery are usually grown in 3-rod or 8-rod rows, depending on the quantity of seed available. In some cases it is possible to discard some of the varieties the first year, but usually they are grown two years. By that time it is possible to discard the poor varieties, while the most promising ones are increased.

In the improvement experiments the starting point is usually the head row. From the head row the good selections are grown in 3-rod or 8-rod rows, depending on the quantity of seed available. After being tested in 8-rod rows for two years it is usually possible to discard the poor selections. The more promising ones either are increased or continued in 8-rod rows. When they are increased they are usually grown in a hundredth-acre or fiftieth-acre plat for one or two years before being grown in the regular varietal test.

The selections in head rows are sown by hand. In all the other nursery work the seeding is done with a grain drill. In seeding the 3-rod and 8-rod rows alternate holes in the drill are closed and the rows sown 1 foot apart. The rows are harvested by hand and thrashed in the nursery thrasher. Complete notes are taken on all selections and varieties.

EXPERIMENTS WITH WHEAT.

Wheat is the most important grain crop in Montana. For this reason the experiments with this crop have been more extensive than those with any of the other cereals. The experiments at the Judith Basin substation have included plat and nursery tests with both spring and winter wheats. Rate-of-seeding and date-of-seeding experiments with these cereals have also been conducted.

WINTER WHEAT.

In 1915 the production of winter wheat in Montana exceeded the production of spring wheat by nearly 3,000,000 bushels. In the Judith Basin winter wheat is grown almost exclusively. In the eastern part of the State winter wheat can be grown only in favorable years. In some years good yields are produced, but there is likely to be winterkilling, so that it is not a sure crop. It is not possible to draw any definite line marking the boundary of the winter-wheat area in the State. At Forsyth, in the eastern part of Rosebud County, winter wheat can be grown successfully. East of Forsyth it can hardly be recommended, although it has been grown as far east as Glendive.

Where winter wheat can be grown successfully it yields more than spring wheat. It is thought that the results obtained from the winter-wheat tests at the Judith Basin substation are applicable wherever the crop can be grown in the State.

VARIETAL EXPERIMENTS IN FIELD PLATS.

ANNUAL RESULTS.

The varietal experiments with winter wheat at Moccasin have included the varieties and strains that have given the best results in the winter-wheat section of the Great Plains area. The varieties have been grown on fallow ground each year. The plats have been either one-tenth acre or 1 acre.

In the fall of 1908, 15 varieties and strains of winter wheat were obtained from McPherson, Kans. These were sown September 18, which is too late for the best results in the Judith Basin. Owing to the late seeding there was considerable winterkilling. Six varieties sown 10 days later winterkilled entirely. In 1909 nine more varieties and strains were obtained from the Nephi (Utah) substation.

Table X gives the annual and average yields of 24 varieties of winter wheat that have been grown at the Judith Basin substation during periods of varying length in the seven years from 1909 to 1915, inclusive. In this table the varieties are grouped according to their relationships. Within the groups they are arranged alphabetically.

TABLE X.—*Annual and average yields of varieties of winter wheat at the Judith Basin substation, Moccasin, Mont., 1909 to 1915, inclusive.*

Group and variety.	C. I. No.	Yield per acre (bushels).									
		1909	1910	1911	1912	1913	a 1914	a 1915	Average.		
									Three years (1909 to 1911).	Five years (1909 to 1913).	Seven years (1909 to 1915).
Crimean:											
Alberta Red.....	2979	.....	37.0	38.5	16.0	a 34.0	25.5	49.1	.....	.....	b 33.3
Armavir.....	1355	.....	36.3	30.0	.....	.....	.....	.....	.....	.....	.....
Beloglina.....	1543	26.7	40.5	29.8	.....	.....	.....	.....	32.3	.....	.....
Do.....	1544	25.0	32.7	34.8	8.0	.....	.....	.....	30.8	.....	.....
Crimean.....	1432	23.7	34.0	40.3	12.7	31.8	.....	.....	32.7	28.5	.....
Do.....	1433	15.3	32.4	34.0	9.5	.....	.....	.....	27.2	.....	.....
Do.....	1435	30.7	40.1	33.3	18.0	a 28.0	23.8	49.5	34.7	30.0	31.9
Do.....	1436	24.2	34.2	32.7	11.5	30.0	.....	.....	30.4	26.5	.....
Do.....	1437	27.5	37.4	40.2	14.7	a 35.3	22.7	51.0	35.0	31.0	32.7
Do.....	1559	25.0	35.3	40.0	10.0	35.0	22.4	49.2	33.4	29.0	30.9
Kharkof.....	1442	20.7	46.2	43.3	17.0	a 33.1	25.5	49.0	36.7	32.0	33.5
Do.....	1583	32.8	48.0	41.3	22.7	a 31.1	24.5	49.4	40.7	35.2	35.7
Torgova.....	1539	25.0	30.4	29.2	.....	.....	.....	.....	28.2	.....	.....
Turkey.....	1532	18.3	29.4	33.7	14.0	29.0	.....	.....	27.1	24.9	.....
Do.....	1571	23.3	41.6	37.7	21.5	29.7	.....	.....	34.2	30.7	.....
Do.....	1576	.....	28.4	28.7	.....	.....	.....	.....	.....	.....	.....
Do.....	1558	21.7	43.7	43.7	22.7	a 32.1	25.8	49.2	36.4	31.8	34.1
Do.....	2998	.....	23.6	30.7	13.6	35.5	.....	.....	.....	.....	.....
Hungarian:											
Bacska.....	1562	.....	28.0	26.7	.....	.....	.....	.....	.....	.....	.....
Weissenberg.....	1563	24.7	35.3	33.7	.....	.....	.....	.....	31.2	.....	.....
Miscellaneous:											
Currell.....	2906	.....	22.6	31.7	.....	.....	.....	.....	.....	.....	.....
Ghirka Winter.....	1438	.....	23.6	33.0	.....	.....	.....	.....	.....	.....	.....
Koffoid.....	2997	.....	19.8	34.2	.....	.....	.....	.....	.....	.....	.....
Zimmerman.....	2907	.....	25.4	33.0	.....	.....	.....	.....	.....	.....	.....

a Yields from acre plats.

b Average for six years only, 1910 to 1915.

As stated previously, the yields in 1909 were lowered on account of winterkilling. The average survival on the winter-wheat plats in the spring of 1909 was 41 per cent. Wheat that was sown early did not suffer from winterkilling and yielded from 45 to 50 bushels per acre.

In 1910 and 1911 the seasonal precipitation was below the average, but as there was no hot weather and most of the seasonal rainfall came in May and June, good yields were obtained.

In 1912 the rainfall in May was above normal, while the precipitation for June was nearly 3 inches below normal. As a result the winter-wheat varieties headed early. A local hailstorm on July 11, when the wheat was fully headed, reduced the yields about 50 per cent.

In 1913 conditions were about normal and an average crop was produced. In 1914 there was abnormally heavy rainfall in May and June, followed by unusually hot, dry weather in July. This caused the wheat to ripen early. The yields were the lowest recorded at the station, with the exception of those produced in 1912, and the quality of grain was poor.

In 1915 the temperature during the growing season was below normal, while the rainfall was more than 2 inches above normal.

The yields produced were the highest ever recorded at the station. Figure 6 shows the winter-wheat varieties grown in replicated fiftieth-acre plats in 1915.

In the fall of 1912 and of each succeeding year the seven leading varieties of winter wheat were seeded on acre plats. This change was made in order to test these varieties on a large scale under actual field conditions and to have seed of the best varieties available for distribution. Table XI gives the annual and average yields of these seven varieties on acre plats in the three years, 1913, 1914, and 1915. The land where these varieties were grown was not always in the best of tilth. The plan was to give the land only such cultiva-

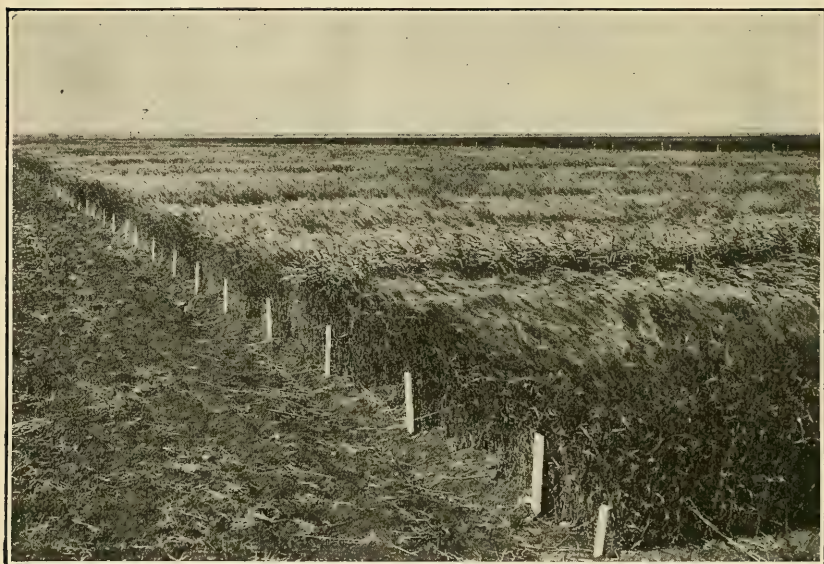


FIG. 6.—Replicated plats of winter-wheat varieties at the Judith Basin substation, 1915. (From a photograph lent by the Office of Exhibits, U. S. Department of Agriculture.)

tion as it would receive under average farm conditions. The yields from the acre plats were not as high as the yields of the same varieties grown in the smaller plats.

TABLE XI.—*Annual and average yield of seven varieties of winter wheat grown in acre plats at the Judith Basin substation, Moccasin, Mont., in the three years from 1913 to 1915, inclusive.*

Variety.	C. I. No.	Yield per acre (bushels).				Variety.	C. I. No.	Yield per acre (bushels).			
		1913	1914	1915	Average.			1913	1914	1915	Average.
Alberta Red.....	2979	34.0	25.5	49.1	36.2	Kharkof.....	1442	33.1	25.5	49.0	35.9
Crimean.....	1435	28.0	23.8	49.5	33.8	Do.....	1583	31.1	24.5	49.4	35.0
Do.....	1437	35.3	22.7	51.0	36.3	Turkey.....	1558	32.1	25.8	49.2	35.7
Do.....	1559	35.0	22.4	49.2	35.5						

Table XI shows that with the exception of the Crimean (C. I. No. 1435) there is little difference in the average yields of the different varieties. In 1913 the Kharkof (C. I. No. 1583) was grown on the outside plat in the series. There was considerable blowing of the soil during the fall and winter, and in consequence the stand and yield of this plat were reduced.

SUMMARY OF WINTER-WHEAT YIELDS.

Of the varieties that have been tested in plats, only six have been grown during the full period. One additional variety, the Alberta Red, has been grown for six years. The yields of these seven varieties are from acre plats in 1913, 1914, and 1915, and are not quite as high as they would have been had the varieties been grown in small plats under more favorable conditions.

Table X shows that of these varieties the Kharkof (C. I. No. 1583) has the highest average yield, 35.7 bushels per acre. This variety was also the highest in average yield in the 3-year and 5-year periods. A study of the yields of the Kharkof (C. I. No. 1583) shows that in 1909 and 1910 it was the highest yielding variety. In 1909 the stands of the varieties were reduced by winterkilling and the Kharkof came through with a higher percentage of survival than any of the others. In 1910, when the seasonal precipitation was the lowest recorded at the substation, the yield of the Kharkof wheat was considerably higher than that of any of the other varieties.

LEADING VARIETIES OF WINTER WHEAT.

Of the 24 varieties of winter wheat that are listed in Table X no less than 18 belong to the Crimean group. These wheats have bearded spikes with white glabrous glumes and hard red kernels. They were imported into this country from southern Russia and are now extensively grown in the central Great Plains and the Pacific Northwest. They are the most important varieties of winter wheat grown in Montana.

The Turkey is probably the best known variety, but the Kharkof and Crimean scarcely can be distinguished from it. The Kharkof, which has been the leading variety of winter wheat at the Judith Basin substation, is thought to be a superior strain of the Crimean group. It seems to be more hardy and to stand drought better than the other varieties, although there are not very large differences in the average yield of the Kharkof, Turkey, and Crimean varieties.

The Kharkof wheat has been increased for distribution among the farmers. This work was started in 1912 and since that time about 2,000 bushels have been sold from the station to farmers for

seed. This seed has been distributed not only among the farmers in the Judith Basin, but in other parts of the State as well. Reports obtained from farmers who are growing this variety in different parts of Montana indicate that they consider it better than other similar varieties. Some farmers claim that the Kharkof yields from 5 to 10 bushels more than any common strain of Turkey which they had been growing.

The average dates of seeding, heading, and maturity, the height, yield per acre of grain and of straw, and weight per bushel of the seven leading varieties of winter wheat are given in Table XII.

TABLE XII.—Average dates of seeding, heading, and maturity, days from seeding to maturity, height, yield of grain and straw, and weight per bushel of seven leading winter-wheat varieties at the Judith Basin substation, Moccasin, Mont., in seven years, 1909 to 1915, inclusive.

Variety.	C. I. No.	Average date—			Seeding to maturity.	Height.	Yield per acre.		Weight per bushel.
		Sown.	Headed.	Ripe.			Grain.	Straw.	
					<i>Days.</i>	<i>Inches.</i>	<i>Bushels.</i>	<i>Pounds.</i>	<i>Pounds.</i>
Alberta Red.....	2979	Sept. 1	June 27	Aug. 4	338	39	^a 33.3	3,292	59.6
Crimean.....	1435	..do.....	..do.....	..do.....	338	38	31.9	3,660	59.8
Do.....	1437	..do.....	..do.....	..do.....	338	39	32.6	3,680	60.1
Do.....	1559	..do.....	..do.....	..do.....	338	38	30.9	3,690	60.1
Kharkof.....	1442	..do.....	..do.....	..do.....	338	38	33.5	3,690	59.6
Do.....	1583	..do.....	..do.....	..do.....	338	37	35.6	3,550	60.1
Turkey.....	1558	..do.....	..do.....	..do.....	338	38	34.1	3,660	60.5

^a Average for six years, 1910-1915, inclusive.

VARIETAL EXPERIMENTS IN NURSERY ROWS.

The nursery work with winter wheat at the Judith Basin substation has included the testing of new varieties and strains and the making and testing of selections. New varieties are usually grown in nursery rows, in order to determine their hardiness and something of their yielding powers before they are tested in plats.

In 1909 a large number of head selections were made from some of the best varieties. These were sown in head rows and the most promising were saved and sown in increase rows in 1910. Additional selections were made in 1910 and 1911, partly within the pure lines and partly from the mass varieties. In every case the selections appearing most promising the next year were saved and grown again.

In 1912 various selections were grown in hundredth-acre plats, 8-rod rows, and in head rows. The hail that year almost completely destroyed the winter-wheat nursery. No yields could be determined, though some plants survived the hail. From the records of previous years it was possible to determine which were the most promising selections. Some seed of these was obtained from surviving plants and sown that fall. Most of the selections had then been grown long enough to determine which were the most promising. Since that

time most of the effort in the nursery work has been devoted to studying and increasing the selections already made rather than to the making of new ones.

At the present time nine selections are being grown in replicated plats in comparison with the mass variety, the Kharkof (C. I. No. 1583). Milling and baking tests are being conducted to determine their value in comparison with commercial varieties.

DATE-OF-SEEDING EXPERIMENTS.

Date-of-seeding tests with winter wheat have been conducted for six years. During the first three years, the Turkey (C. I. No. 1558) was used, while during the last three years the Kharkof (C. I. No. 1583) was sown. The dates included have ranged from August 1 to October 15. The results of these experiments have been rather variable, due, no doubt, to the variations in climatic conditions during August and September of the different years. In 1909 the earliest seeding, August 1, gave the best results. In that year there was considerable winterkilling in the late-sown plats. On the average, the best results have been obtained from plats sown between August 12 and September 20. It may happen in some years that there is not enough moisture in the soil in August and September to help germinate the wheat and give it a good start. When this condition occurs, late seeding is likely to be better than early seeding.

Table XIII gives the data that have been recorded in the date-of-seeding experiment. From this table it will be seen that in the six years the early September seeding (Sept. 1 to 7) has produced the highest average yield. There is little difference between the yields produced from seeding at this date and from seeding either about August 15 or September 15. It is probable that seeding between August 10 and September 20 will give good results. Wheat seeded after the later date is likely to get a poor start in the fall and therefore to winterkill.

TABLE XIII.—*Annual and average yields obtained in a date-of-seeding test with winter wheat at the Judith Basin substation, Moccasin, Mont., during the six years from 1909 to 1914, inclusive.*

Date of seeding.	Yield per acre (bushels).						
	1909	1910	1911	1912	1913	1914	Average.
							1911 to 1914. All years sown.
Aug. 1 to 7.....	60.5	36.0	30.3	(¹)	28.0	(¹)	38.7
Aug. 12 to 17.....	32.0	38.6	31.0	16.7	32.5	28.7	29.8
Sept. 1 to 7.....	24.5	36.5	35.6	20.0	46.0	28.7	31.9
Sept. 15 to 20.....	25.2	(¹)	35.3	16.3	35.0	30.0	28.3
Oct. 1.....	0	24.0	30.0	17.5	26.8	23.3	20.3
Oct. 15.....	(¹)	(¹)	29.3	9.1	17.3	28.8	21.1

¹ Not sown.

Table XIII shows that the average yield of plats sown October 1 and October 15 is from 10 to 11 bushels per acre less than that of plats sown September 1 to 7.

In all the varietal tests at the Judith Basin substation an effort has been made to sow winter wheat early; that is, between August 10 and September 10. In 1908, the only year when there was much winterkilling, the seeding was late because the seed was not available earlier.

RATE-OF-SEEDING EXPERIMENTS.

Rate-of-seeding experiments with winter wheat were started in 1909 and conducted for six years. During the first three years, the Turkey (C. I. No. 1558) was used, while during the last three years the Kharkof (C. I. No. 1583) was sown. The rates of seeding ranged from 2 to 8 pecks per acre. Table XIV contains the data that have been obtained from these tests. This table shows that there is but little difference in the yields produced from the 3-peck and the 4-peck rates of seeding, the rates from which the highest yields have been obtained.

Because of the free tillering of winter wheat it is not necessary to seed heavily in order to get a good stand. Seeding more than 4 pecks to the acre not only reduces the yield but also the quality of the grain. Three pecks is the rate usually sown by farmers in the Judith Basin and is the one at which all of the plats in the varietal tests are sown.

TABLE XIV.—*Annual and average yields obtained in a rate-of-seeding test with winter wheat at the Judith Basin substation, Moccasin, Mont., during six years, 1909 to 1914, inclusive.*

Rate of seeding.	Yield per acre (bushels).							
	1909	1910	1911	1912	1913	1914	Average.	
							1909 to 1914	1910 to 1913
2 pecks.....	16.4	36.5	33.3	16.7	27.7	25.0	25.8	28.5
3 pecks.....	32.0	41.5	37.3	18.6	32.5	28.8	31.8	32.5
4 pecks.....	35.4	38.0	35.0	21.7	30.3	27.8	31.2	31.2
5 pecks.....	.....	35.0	35.0	19.0	25.7	.....	.....	28.7
6 pecks.....	23.6	31.6	35.3	20.4	26.7	.....	.....	28.5
8 pecks.....	22.8	28.2	36.8	20.7	27.0	.....	.....	28.2

SPRING WHEAT.

Spring wheat is not as important a crop in Montana as winter wheat. In the Judith Basin the acreage of spring wheat is very small in comparison with that of winter wheat. In the eastern part of the State, where winter wheat is not a sure crop, spring wheat is of more importance.

The work with spring wheat at Moccasin has included field plat and nursery tests. The varieties tested have included those that have given the best results in other dry-land districts of the Great Plains area.

The spring-wheat varieties are sown at the rate of 4 pecks to the acre. The date of seeding has been governed by the climatic conditions. The best results are obtained from seeding as early as soil and weather conditions in the spring will permit. This date varies, of course, in different years.

VARIETAL EXPERIMENTS IN FIELD PLATS.

ANNUAL RESULTS.

The varietal testing of spring wheat was started in 1908, when 20 varieties were grown. They were sown on ground that had been broken in 1907 and the seed bed was not in good tilth when the varieties were sown on May 5. The precipitation for June and July was below normal. As a result of the low precipitation and poor seed bed low yields were obtained from all varieties.

In 1909 the varieties were sown on well-prepared fallow ground. The seeding was not done until May 12. The precipitation that year was above normal and good yields were obtained from all varieties.

In 1910 the varieties were sown on April 19. The precipitation was below normal; in fact, the seasonal precipitation for 1910 was the lowest recorded since the substation was established. The yields of all varieties were low, the average for the 23 varieties tested being 11.4 bushels per acre. A surprising fact in this year was that the spring common wheats outyielded the durum varieties. This result was contrary to the general opinion that the durum varieties are more resistant to drought than the spring common wheats. Low yields of durum varieties were obtained at several of the field stations in the Great Plains in 1910.

In 1911, because of a shortage of summer-fallowed land, the spring-wheat varieties were sown in twentieth-acre plats. The seeding was done April 20 in a well-prepared seed bed. The precipitation in May and June was about normal, but there was only 0.5 inch of rain in July. This was followed by excessive rainfall in August, which came in time to benefit the spring wheats. The total for the month was 6.34 inches. All varieties produced good yields and the quality of the grain was good.

In 1912 the precipitation for June was nearly 2 inches below normal. This was accompanied by rather hot weather. The spring-wheat varieties were just beginning to head on July 12, when they were completely destroyed by a severe hailstorm. While most varieties made some second growth no grain was produced.

A change was made in the method of testing the spring-wheat varieties in 1913. Instead of seeding them in single tenth-acre or twentieth-acre plats they were sown in fiftieth-acre plats and each variety replicated five times. Seeding was done on April 21 on well-prepared fallow ground. The crop that year was produced under normal conditions.

In 1914 the spring wheat was again grown in replicated fiftieth-acre plats. The seeding was done on April 20. The precipitation in May and June was above normal. Hot, dry weather in July and August caused the wheat to ripen early and reduced the yields.

The year 1915 was marked by abnormally high rainfall and low temperatures during most of the growing season. The spring wheat was sown in replicated plats on April 9. The yields were the highest recorded at the substation.

SUMMARY OF SPRING-WHEAT YIELDS.

Table XV gives the annual and average yields of 25 varieties of spring wheat grown in plat tests at the Judith Basin substation during periods of varying length from 1908 to 1915, inclusive.

This table shows that the Galgalos (C. I. No. 2398) has produced the highest average yield both for the 4-year period (1908-1911) and the 7-year period (1908-1911 and 1913-1915). This wheat is a soft variety and is of less value for milling purposes than the hard wheats. The next highest yielding variety is a durum wheat, the Pelissier (C. I. No. 1584). This variety has a 7-year average yield of 27.2 bushels per acre, which is only 0.4 of a bushel less than the yield of the Galgalos. The durum group, as a whole, has yielded higher, on the average, than any other group.

TABLE XV.—*Annual and average yields of 25 varieties of spring wheat grown in plat tests at the Judith Basin substation, Moccasin, Mont., during periods of varying length in seven years, 1908 to 1911 and 1913 to 1915, inclusive.*¹

Group and variety.	C. I. No.	Yield per acre (bushels).							Average.		
		1908	1909	1910	1911	1913	1914	1915	1908 to 1911	1908 to 1911, 1913 to 1915	For period grown.
Durum group:											
Arnautka.....	1493	10.0	36.7	10.0	25.0	-----	-----	-----	20.4	-----	20.4
Do.....	1494	10.0	33.0	7.6	31.7	-----	-----	-----	20.6	-----	20.6
Beloturka.....	1520	9.5	40.3	6.5	29.0	30.0	25.2	40.1	21.3	25.8	25.8
Bledur.....	1471	7.5	28.3	9.5	29.0	-----	-----	-----	18.6	-----	18.6
Gharnovka.....	1447	5.0	35.8	10.0	30.3	-----	-----	-----	20.3	-----	20.3
Kubanka.....	1440	5.0	37.8	8.8	33.0	30.7	23.0	40.7	21.1	25.5	25.5
Pelissier.....	1584	10.0	41.0	10.5	28.3	32.0	26.5	42.2	22.5	27.2	27.2
Pererodka.....	1350	5.0	36.7	12.7	36.0	32.0	25.3	40.1	22.6	26.8	26.8
Purple.....	3024	10.0	39.0	8.5	26.0	-----	-----	-----	20.9	-----	20.9
Taganrog.....	1570	3.3	36.3	16.3	24.3	-----	-----	-----	20.0	-----	20.0
Velvet Don.....	1445	7.5	32.3	6.1	26.0	-----	-----	-----	18.0	-----	18.0
Yellow Gharnovka.....	1444	15.0	39.3	8.2	27.7	32.8	25.0	39.2	22.5	26.8	26.8
Fife group:											
Cole Hybrid (No. 61)....	4062	-----	30.3	10.2	31.0	29.7	22.5	38.0	-----	-----	26.9
Ghirka Spring.....	1517	3.3	34.2	13.2	25.2	29.0	23.0	38.0	19.0	23.7	23.7
Glyndon (Minn. No. 163).....	2873	-----	-----	-----	28.0	20.0	22.7	41.0	-----	-----	27.9
Marquis.....	3641	-----	-----	-----	-----	33.5	23.7	42.3	-----	-----	33.1
Power.....	3697	-----	-----	-----	-----	28.7	24.1	41.0	-----	-----	31.2
Rysting.....	3022	2.5	29.0	13.0	27.0	26.7	23.0	40.7	18.0	23.1	23.1
Preston group:											
Fretes.....	1596	7.5	23.9	16.8	32.7	35.2	25.7	42.5	20.2	26.3	26.3
Preston (Minn. No. 188)....	2958	-----	31.0	13.5	25.0	29.2	22.4	41.6	-----	-----	27.1
South Dakota Climax.....	-----	-----	29.3	14.6	24.7	-----	-----	-----	-----	-----	22.5
Bluestem group:											
Haynes (Minn. No. 169)....	2874	-----	29.7	9.1	18.7	-----	-----	-----	-----	-----	19.2
Haynes (Minn. No. 51)....	3021	5.0	30.0	11.7	21.0	-----	-----	-----	17.0	-----	17.0
Miscellaneous:											
Galgalos.....	2398	7.5	40.2	18.5	31.3	30.7	24.5	40.5	24.4	27.6	27.6
-----	2116	-----	-----	14.8	24.7	27.3	20.7	-----	-----	-----	21.9

¹ The crop of 1912 was entirely destroyed by hail.

LEADING VARIETIES OF SPRING WHEAT.

Of the 25 varieties of spring wheat that are listed in Table XV only 9 have been grown during the entire period. Of these, 5 belong to the durum group, 2 to the Fife group, 1 to the Preston group, and 1 is a miscellaneous variety. Table XVI gives the average dates of seeding, heading, and maturity, the average height and weight per bushel, and the average yields of grain and of straw from each variety during the seven years. From this table it will be seen that, as a group, the durum varieties yield higher than the other groups.

TABLE XVI.—Average dates of seeding, heading, and maturity, days from seeding to maturity, height, yield of grain and straw, and weight per bushel of nine leading spring-wheat varieties at the Judith Basin substation, Moccasin, Mont., during seven years, 1908 to 1911 and 1913 to 1915, inclusive.

Group and variety.	C. I. No.	Average date—			Seed- ing to matur- ity.	Height, ¹	Yield per acre.		Weight per bushel. ²
		Seeded.	Headed.	Ripe.			Grain.	Straw.	
Durum group:					<i>Days.</i>	<i>Inches.</i>	<i>Bush.</i>	<i>Lbs.</i>	<i>Lbs.</i>
Beloturka.....	1520	Apr. 24	July 16	Aug. 24	122	43.5	25.8	3,108	59.6
Kubanka.....	1440	..do....	July 17	Aug. 26	124	42.5	25.5	3,073	59.6
Pelissier.....	1584	..do....	..do....	..do....	124	43.0	27.2	2,950	60.0
Pererodka.....	1350	..do....	July 15	Aug. 25	123	42.0	26.8	3,200	59.8
Yellow Gharovka.....	1444	..do....	July 16	Aug. 26	124	42.6	26.8	3,172	59.8
Fife group:									
Ghirka Spring.....	1517	..do....	July 17	Aug. 25	123	37.5	23.7	2,576	59.0
Rysting.....	3022	..do....	July 20	Aug. 27	125	39.0	23.1	2,796	59.2
Preston group:									
Fretes.....	1596	..do....	July 18	Aug. 25	123	38.0	26.3	3,131	59.4
Miscellaneous:									
Galgalos.....	2398	..do....	July 16	Aug. 26	124	35.5	27.6	2,500	59.6

¹ Average for six years, 1909 to 1911 and 1913 to 1915, inclusive.

² Average for five years, 1910, 1911, and 1913 to 1915, inclusive.

Durum wheat.—The leading durum wheat is the Pelissier (C. I. No. 1584). This variety has white glabrous glumes and black awns. The kernels are large, hard, and of a clear amber color. The other durum varieties that have been grown at Moccasin belong to the Kubanka group. They have glabrous yellow glumes and yellow awns.

Common wheat.—Among the common wheats that have been tried, the Galgalos (C. I. No. 2398) has produced the highest 7-year average yield. This variety is beardless, with brown pubescent glumes and rather large soft white kernels. While it yields well it is considered by millers to be poor in quality as compared with the hard wheats.

Of the Fife group, only two varieties have been grown during the full period. These are the Rysting and Ghirka. The Ghirka ripens about the same time as the durum varieties, while the Rysting is somewhat later. These two varieties have yielded from 3 to 4 bushels less than the durum wheats.

The Fretes (C. I. No. 1596) is the only variety belonging to the Preston group that has been grown during the seven years. This

variety yields a little more than the Fife varieties, but not quite as much as the durumms.

Table XVII gives the annual and average yields of the leading variety in each of the groups for 1913, 1914, and 1915. From this table it will be seen that the Fretes leads, with the Pelissier second and the Marquis third. The Marquis has been grown at Moccasin for only three years. During that time it has been among the highest yielders and is also of high milling quality. A view of plats of the Marquis and Beloturka varieties, the latter a durum wheat, is shown in figure 7.

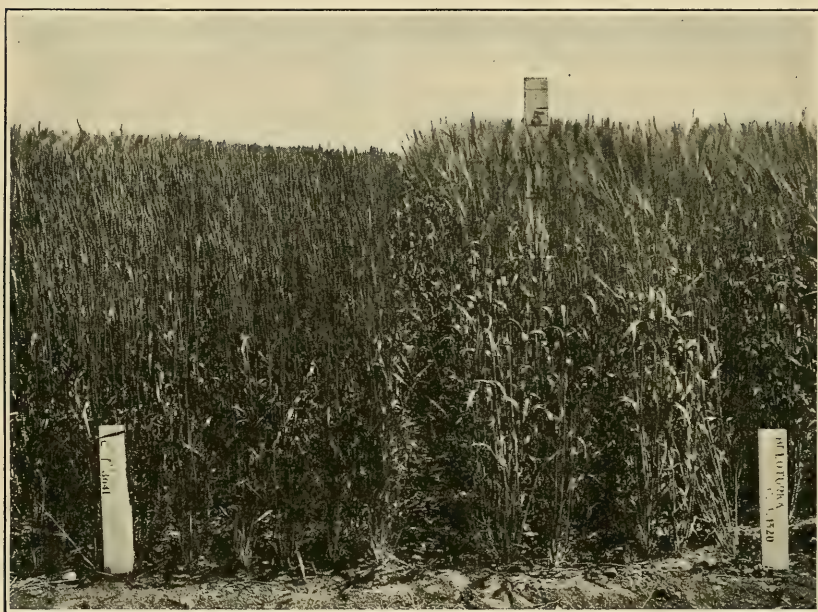


FIG. 7.—End view of plats of the Marquis and Beloturka wheats, the latter a durum variety. (From a photograph lent by the Office of Exhibits, U. S. Department of Agriculture.)

TABLE XVII.—*Annual and average yields of the leading variety in each group of spring wheat grown at the Judith Basin substation, Moccasin, Mont., during three years, 1913 to 1915, inclusive.*

Group and variety.	C. I. No.	Yield per acre (bushels).				Group and variety.	C. I. No.	Yield per acre (bushels).			
		1913	1914	1915	Average.			1913	1914	1915	Average.
Durum group:						Preston group:					
Pelissier	1584	32.0	26.5	42.2	33.6	Fretes	1596	35.2	25.7	42.5	34.5
Fife group:						Miscellaneous:					
Marquis.....	3641	33.5	23.7	42.3	33.2	Galgals.....	2398	30.7	24.5	40.5	31.9

VARIETAL EXPERIMENTS IN NURSERY ROWS.

The nursery work with spring wheat has been conducted along the same general lines as that with winter wheat. The work was started

in 1909, when 206 varieties and selections were grown in 2-rod rows. In 1910 and 1911 head selections were made from the most promising varieties. In 1912 the spring-wheat nursery was completely destroyed by hail. A reserve supply of seed of a few of the selections was available and was sown in 1913. At the present time several selections have been increased and are being tested in fiftieth-acre plots.

COMPARISON OF SPRING AND WINTER WHEATS.

Table XVIII gives the annual and average yields of the leading varieties of spring and winter wheats during six years, 1909 to 1911 and 1913 to 1915, inclusive. The average yields are shown graphically in figure 8. Since the spring wheat was destroyed by hail in 1912, it was necessary to omit that year. The table shows that on the

WINTER WHEAT

KHARKOF, C. I. N° 1583--	38.0 BU.
KHARKOF, C. I. N° 1442--	36.3 BU.
TURKEY, C. I. N° 1558---	36.0 BU.

SPRING WHEAT

PELISSIER, C. I. N° 1584--	30.2 BU.
GHIRKA SPRING, C. I. N° 1517	27.1 BU.
FRETES, C. I. N° 1596---	29.4 BU.
GALGALOS, C. I. N° 2398-	30.9 BU.

FIG. 8.—Diagram showing the average yields of winter and spring wheat varieties at the Judith Basin substation for six years, 1909 to 1911 and 1913 to 1915, inclusive.

average the winter wheats outyield the spring varieties by about 8 bushels per acre. Heads of representative varieties of the various groups of wheat are shown in figure 9.

TABLE XVIII.—Annual and average yields of leading varieties of winter and spring wheat grown at the Judith Basin substation, Moccasin, Mont., in the six years 1909 to 1911 and 1913 to 1915, inclusive.

Group and variety.	C. I. No.	Yield per acre (bushels).						
		1909	1910	1911	1913	1914	1915	Average.
WINTER WHEAT.								
Crimean:								
Kharkof.....	1583	32.8	48.0	41.3	31.1	24.5	49.4	38.0
Do.....	1442	20.7	46.2	43.3	33.1	25.5	49.0	36.3
Turkey.....	1558	21.7	43.7	43.7	32.1	25.8	49.2	36.0
SPRING WHEAT.								
Durum:								
Pelissier.....	1584	41.0	10.5	28.3	32.6	26.5	42.2	30.2
Fife:								
Ghirka.....	1517	34.2	13.2	25.2	29.0	23.0	38.0	27.1
Preston:								
Fretes.....	1596	23.9	16.8	32.7	35.2	25.7	42.5	29.4
Miscellaneous:								
Galgalos.....	2398	40.2	18.5	31.3	30.7	24.5	40.5	30.9

In 1909, when there was considerable winterkilling of the winter wheats, the spring wheats produced the larger yields. In 1910 and 1911, which were both years of drought, the winter varieties out-yielded the spring wheats. In 1913 and 1914 the yields were about equal. In 1915, when the rainfall was abnormally high, the winter wheats yielded 6 to 7 bushels more than the spring varieties. For the six years the average yield of the best winter wheat is 7.8 bushels higher than that of the best spring wheat. It should be remembered that the yields of winter wheat in 1913, 1914, and 1915 are from acre plats, while those of spring wheat are from replicated fiftieth-acre plats.

The growing of winter wheat is to be recommended in the Judith Basin and generally in Montana wherever it is practicable, because the

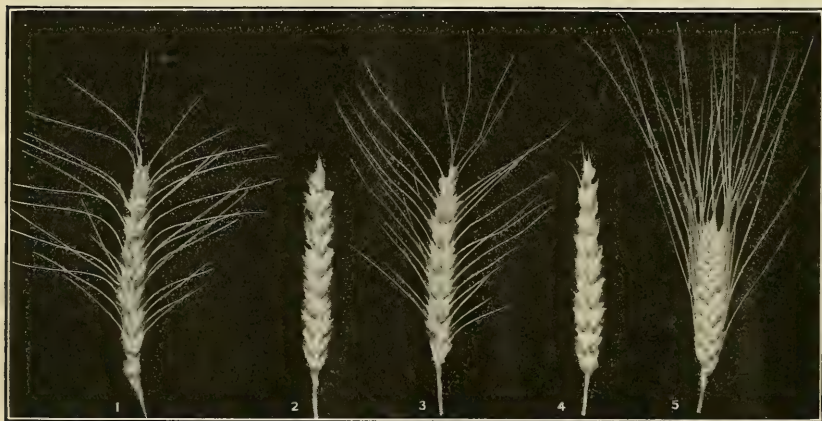


FIG. 9.—Heads of representative varieties of some of the important groups of wheat: 1, Turkey; 2, Fife; 3, Preston (bearded spring); 4, bluestem; and 5, durum.

average yield is higher than that of spring wheat. In a very dry year it may yield from three to four times as much as the spring varieties.

EXPERIMENTS WITH OATS.

Next to wheat, oats are the most important cereal crop in Montana. In 1915 the area sown to oats in the State was estimated at 600,000 acres, with an average yield of 52 bushels per acre. Oats are not grown as a cash crop like wheat, but for feeding. The yields obtained at Moccasin are quite satisfactory and show that oats usually can be successfully grown on the dry lands of the State.

In the varietal tests at Moccasin the small-kerneled early oats have been sown at the rate of 4 pecks per acre. Seeding tests show but little difference in the results obtained from the 4-peck and 5-peck rates. In dry years, however, the lower rate of seeding gives the best yields. The larger kerneled varieties are sown at the rate of 5 pecks per acre. In a date-of-seeding test the best results were obtained

from seeding as early in the spring as soil and climatic conditions permitted. In all the varietal work the effort has been to seed as early as possible.

VARIETAL EXPERIMENTS IN FIELD PLATS.

Table XIX gives the annual and average yields of 24 varieties of oats grown in plats at the Judith Basin substation from 1908 to 1915. Of the 24 varieties in this table, only 3 have been tested during the



FIG. 10.—Heads of representative varieties of oats (left to right): 1, White Russian; 2, Siberian; 3, Swedish Select; and 4, Sixty-Day.

entire period and only 14 of them are now being grown. Heads of representative varieties of oats are shown in figure 10.

In 1908 the oats were sown in a poor seed bed. Because of this and the drought in June and July, the yields were low. The year 1909 was one of abnormally high rainfall and good yields were obtained. In 1910 quite severe drought conditions prevailed during the growing season and the yields were low. It is noticeable that in this year the early oats outyielded the late varieties. In 1911 the oats which ripened before the heavy August rains were the only ones to mature a crop. The rainfall during the month was 6.34 inches. This caused the late oats to make a second growth and they were not ripe when the first frost came. No crop was produced in 1912 be-

cause of hail. In 1913 and 1914 crops were produced under nearly normal conditions, although in 1914 the dry weather in July reduced the yields somewhat. The only year in the period when the late oats outyielded the early ones was 1915, when the rainfall for the growing season was 2 inches above normal and the yields obtained were the highest recorded at the station.

TABLE XIX.—*Annual and average yields of 24 varieties of oats grown in plats at the Judith Basin substation, Moccasin, Mont., for periods of varying length during the eight years from 1908 to 1915, inclusive.*¹

Group and variety.	C. I. No.	Yield per acre (bushels).									
		1908	1909	1910	1911	1913	1914	1915	Average.		
									1908 to 1911	1913 to 1915	1908 to 1911, 1913 to 1915
Early:											
Early Champion		10.0	67.2	5.7	(²)				20.7		
Kherson	459	20.5	80.6	32.0	67.5	68.4	59.0	90.0	50.1	72.5	58.3
Sixty-Day	165	20.5	84.4	33.0	71.2	75.3	59.0	93.7	52.0	76.0	62.4
Sixty-Day selection	789				68.1	78.4	57.2	94.0		76.5	
Do.	625			29.5	58.7	73.4	56.2	88.4		72.7	
Do.	626				53.7	80.0	56.0	95.6		77.2	
Midseason:											
Banner	751					73.8	46.3	99.0		73.0	
Canadian	444	5.0	82.6	14.2	(²)				25.4		
Danish	441	20.0	76.8	23.6	(²)	56.2	47.3	100.0	30.1	67.8	46.2
Dakota No. 4	753						50.0	99.0			
Early Mountain	754	10.0	68.7	5.8							
Garton White			67.8	18.3	(²)						
Golden Rain	493			23.4	(²)						
Lincoln	738						51.0	100.0			
Red Algerian	286	5.5	66.4	15.4	(²)				21.8		
Red Siberian	487		69.2	11.4	(²)						
Silvermine	714						49.0	101.0			
Siberian	741					70.0	46.3	98.7		71.7	
Swedish Select	134	15.0	77.0	22.3	(²)	53.1	50.0	108.0	28.6	70.4	46.5
Victory	742			28.0	(²)		42.9	97.0			
Late:											
Sparrowbill	443	15.0	69.0	20.1	(²)				26.0		
White Russian	471	5.0	81.0	7.6	(²)				23.4		
White Tartarian	300	13.3	67.3	18.0	(²)				24.6		
Yellow Giant	342	15.0	65.0	8.6	(²)				22.1		

¹ Crop destroyed by hail in 1912.

² Made second growth during rainy weather in August; not ripe when the first frost came.

In 1908, 1909, 1910, and 1913 the varieties were grown in unreplicated tenth-acre plats and in 1911 and 1912 in unreplicated twentieth-acre plats. In 1914 and 1915 they were grown in fiftieth-acre plats replicated five times.

LEADING VARIETIES.

The varieties of oats that have been grown at Moccasin may be divided into three groups according to their date of maturity—early, midseason, and late. The early oats have given the best average results.

Data on average dates of heading and of maturity, height, weight per bushel, and yield of grain and of straw for some of the leading

varieties are given in Table XX. The average yields of these varieties are shown graphically in figure 11.

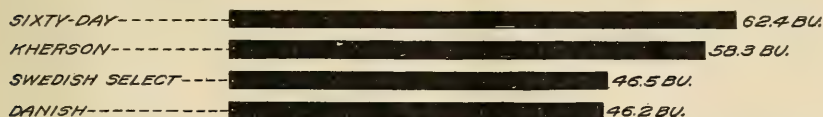


FIG. 11.—Diagram showing the average yields of the leading varieties of oats at the Judith Basin substation for seven years, 1908 to 1911 and 1913 to 1915, inclusive.

TABLE XX.—Average dates of seeding, heading, and ripening, days from seeding to maturity, height, weight per bushel, and yield of grain and straw of five leading oat varieties at the Judith Basin substation, Moccasin, Mont., during the seven years, 1908 to 1911 and 1913 to 1915, inclusive.

Group and variety.	C. I. No.	Average date—			Seed- ing to matur- ity.	Height. ^a	Average yield per acre.			Weight per bushel.
		Sown.	Headed.	Ripe.			Grain.		Straw. ^b	
							1908 to 1911 and 1913 to 1915.	1913 to 1915.		
					Days.	Inches.	Bush.	Bush.	Lbs.	Lbs.
Early yellow: Sixty-Day.....	165	Apr. 29	July 6	Aug. 7	100	36.5	62.4	76.0	2,250	c 34.6
Kherson.....	459	...do....	...do....	...do....	100	36.3	58.3	72.5	2,274	c 34.6
Midseason white:										
Siberian ^d	741	Apr. 21	July 21	Aug. 15	114	48.0	.....	71.7	3,226	36.6
Swedish Select	134	Apr. 29	July 17	Aug. 16	110	42.0	46.5	70.4	2,714	e 37.0
Danish.....	441	...do....	...do....	Aug. 18	111	39.0	46.2	67.8	2,513	e 32.3

^a Average for six years, 1909 to 1911 and 1913 to 1915, inclusive.

^b Average for five years, 1909 and 1910 and 1913 to 1915, inclusive.

^c Average for five years, 1910 and 1911 and 1913 to 1915, inclusive.

^d Average for three years, 1913 to 1915, inclusive.

^e Average for four years, 1910 and 1913 to 1915, inclusive.

EARLY VARIETIES.

The Sixty-Day and Kherson varieties are the only early oats that have been tested at Moccasin during the entire seven years.¹ The Sixty-Day variety was introduced from southwestern Russia into the United States by the United States Department of Agriculture in 1901. The Kherson was imported from the same general locality a few years earlier by the Nebraska Agricultural Experiment Station. Plats of the Kherson and Sixty-Day oats at the Judith Basin substation are shown in figure 12. The two varieties are practically identical. The straw is rather short and fine and the heads loose and spreading. The grain is yellow in color, small, long, and rather slender. The hull is thin, and under favorable conditions the weight per bushel is high. In the Judith Basin these varieties usually reach maturity in 95 to 105 days and are about 10 days earlier than the midseason varieties. At Moccasin the average yield of the Sixty-Day is slightly larger than that of the Kherson. Two pure-line

¹ For a more extended discussion of these varieties, see Warburton, C. W., Sixty-Day and Kherson oats, U. S. Dept. Agr., Farmers' Bul. 395, 27 p., 5 fig., 1910.

selections from the Sixty-Day have slightly exceeded the parent variety in average yield in the years they have been grown.

There is some objection to these oats by farmers because of the yellow color and small size of the kernel. As oats are commonly grown in Montana for feed rather than to sell, the yellow color is not objectionable. Because of the thin hulls, these varieties have a larger proportion of kernel to hull than the larger types of oats.

The Sixty-Day is being increased at the Judith Basin substation. About 2,000 bushels have already been distributed throughout the dry-land areas of the State, and the results obtained seem to indicate that for these lands the Sixty-Day variety is the best.



FIG. 12.—End view of plats of Sixty-Day and Kherson oats at the Judith Station substation, 1915.
(From a photograph lent by the Office of Exhibits, U. S. Department of Agriculture.)

MIDSEASON VARIETIES.

Of the varieties of oats that have been tested at Moccasin, 13 can be classed as midseason in maturity. The Swedish Select is the only one in this group that has been grown in the entire seven years. This variety has a 7-year average yield of 46.5 bushels, which is 15.9 bushels lower than the 7-year average yield of the Sixty-Day. Other typical varieties of this group are the Danish, Lincoln, and Silvermine. All these are more suitable for growing under irrigation than on the dry farms in Montana.

The varieties of the midseason group have tall, coarse straw and large, rather broad grain. They are from a week to 10 days later in maturing than varieties of the early group.

LATE VARIETIES.

All the late varieties which have been grown are side oats. The White Russian, White Tartarian, and other late varieties have not produced good yields at Moccasin except in 1909. In that year they

did not yield more than the early and midseason varieties, while in less favorable years, such as 1908 and 1910, they were considerably lower in yield. The growing of these late side oats was discontinued in 1911. None of them can be recommended for growing on the dry lands in Montana.

EXPERIMENTS WITH BARLEY.

Barley is not as important a crop in Montana as wheat or oats. The estimated area sown to barley in the State in 1915 was 80,000

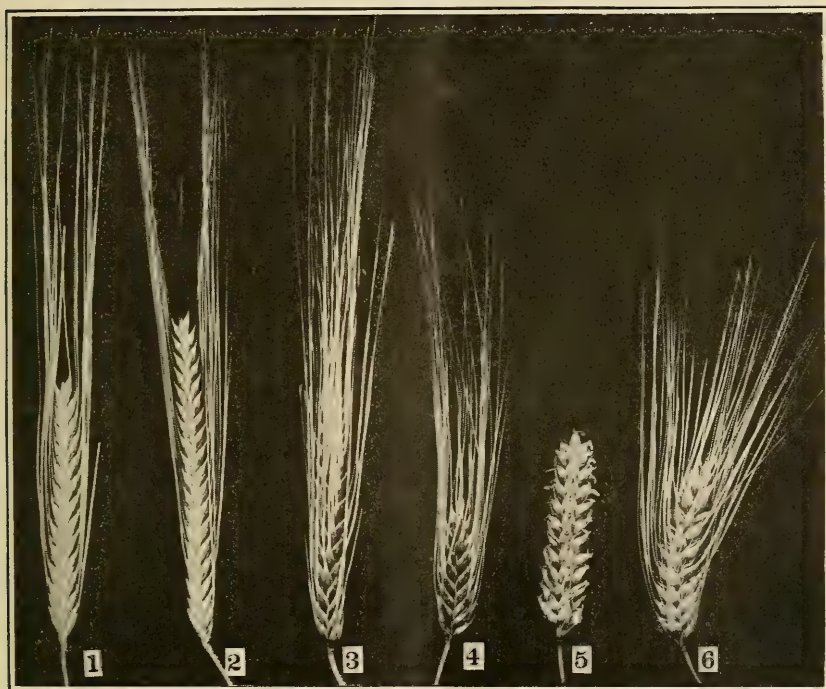


FIG. 13.—Heads of representative varieties of barley: 1, White Smyrna, and 2, Hinnchen, 2-rowed hulled varieties; 3, Coast, and 4, Mariout, 6-rowed hulled varieties; and 5, Nepal, and 6, Himalaya, 6-rowed naked varieties.

acres, about 13 per cent of the oat acreage and 6 per cent of the wheat acreage of that year. The results of the experiments at Moccasin show that good yields of barley can be obtained on dry land and that the crop is a profitable one. Barley is grown chiefly for feeding purposes.

The varietal tests at Moccasin have included both the hulled and the naked, or hull-less, varieties. As with the other spring cereals, early seeding has given the best results. The hulled varieties are seeded at the rate of 5 pecks per acre and the naked varieties at the rate of 4 pecks.

VARIETAL EXPERIMENTS IN FIELD PLATS.

Seven varieties of barley were grown in 1908. Because of the poor seed bed and drought, low yields were obtained. In 1909 fairly good

yields were obtained from all varieties. In 1910 six more varieties were added to the test. Because of the shortage of summer-fallowed land it was necessary to grow the varieties on the ground used for testing barley in 1909. The land was plowed early in the spring and the seeding was done on April 20. The resulting yields were low. In 1911 the hot, dry weather in July reduced the yields, and in 1912 all varieties were destroyed by hail. In 1913 good yields were obtained from all varieties. The hot, dry weather during July, 1914, caused the varieties to ripen early and the quality of the grain was poor. The yields obtained in 1915 were the highest recorded at the station.

The barley varieties were grown in unreplicated tenth-acre plats in 1908, 1909, 1910, and 1913 and in unreplicated twentieth-acre plats in 1911 and 1912. In 1914 and 1915 they were grown in fiftieth-acre plats, replicated five times.

Table XXI gives the annual and average yields of the barley varieties that have been tested at Moccasin from 1908 to 1915. Of the 19 varieties listed in this table, 9 belong to the 2-rowed hulled group, 5 to the 6-rowed hulled group, 2 to the 2-rowed naked group, and 3 to the 6-rowed naked group. Only 3 of the 19 varieties have been grown in all seven years and only 14 are now being grown. Heads of representative varieties of the different groups of barley are shown in figure 13.

TABLE XXI.—*Annual and average yields of 19 varieties of barley grown in plat tests at the Judith Basin substation, Moccasin, Mont., 1908 to 1911 and 1913 to 1915, inclusive.*¹

Group and variety.	C. I. No.	Yield per acre (bushels). ²									
		1908	1909	1910	1911	1913	1914	1915	Average.		
									1910 to 1911, 1913 to 1915	1913 to 1915	1908 to 1911, 1913 to 1915
Two-rowed hulled:											
Bohemian.....	27		48.5	11.2							
Canadian Thorpe.....	740					50.0	36.0	65.1		50.3	
Franconian.....	680						31.2	80.0			
Hannchen.....	531			14.4	45.8	54.3	46.0	78.8	47.9	59.7	
Hanna.....	678						29.5	78.2			
Mansury.....	617	20.0	45.7	13.0	38.3	48.7	38.0	70.8	41.8	52.5	37.8
Svanhals.....	187					48.9	43.5	68.1		53.5	
Thorpe.....	921	10.0	53.3	11.1	28.3	52.6	39.2	66.7	39.6	52.8	37.4
White Smyrna.....	195			12.3	52.0	70.0	50.0	80.3	52.9	66.8	
Six-rowed hulled:											
Beldi.....	190			8.0	43.7	53.7	42.2	73.6	44.2	56.2	
Coast.....	690			15.0	43.7	55.0	43.1	83.1	48.0	60.4	
Gatami.....	575			8.2	34.4						
Manchuria.....	354		45.2	9.8	40.8	39.2	36.0	52.2	35.6	42.5	
Mariout.....	231			16.2	47.0	47.9	51.3	72.0	46.8	57.1	
Two-rowed naked:											
Clyde.....	909					37.5	22.0				
McEvans.....	621	5.5	32.6	10.3	19.3						
Six-rowed naked:											
Black Hull-less.....	596	10.0	43.8	13.6	25.3						
Himalaya.....	620	5.5	33.2	12.3	25.0	43.0	30.3	48.8	31.9	40.7	28.2
Nepal.....	595	20.0	42.4	16.4	30.0	37.0	25.7	41.8	30.2	34.8	30.5

¹ Crop destroyed by hail in 1912.

² Hulled varieties in bushels of 48 pounds; naked varieties in bushels of 60 pounds.

LEADING VARIETIES.

Table XXII shows that the White Smyrna (C. I. No. 195), with a 5-year (1910 to 1911 and 1913 to 1915) average yield of 52.9 bushels, is the leading variety. The White Smyrna is a 2-rowed hulled variety that was obtained from Asia Minor. The head is of medium length and the kernels are large. The straw is rather short, especially in a dry season, and the heads are often imperfectly exerted.

The White Smyrna is being increased at Moccasin for distribution among the farmers. About 1,200 bushels have been sold. The results obtained in other parts of the State agree with those at Moccasin, indicating that the White Smyrna is well adapted to the dry lands of Montana.

The Hannchen is a 2-rowed variety, with a narrow, nodding head, that has given good results at Moccasin. It is a selection from Hanna made by the Swedish Plant Breeding Association, of Svalof, Sweden. This variety grows a little taller than the White Smyrna and is later in maturing. The 5-year average yield of the Hannchen is about 5 bushels less than that of the White Smyrna.

The leading varieties among the 6-rowed hulled group are the Coast and the Mariout.

The Coast variety is known also as California Feed and Bay Brewing barley. It grows taller than the Mariout. The head is not as compact and the beard is not always entirely removed in thrashing. In average yield it has equaled the Hannchen, but the White Smyrna has exceeded it by about 5 bushels.

The Mariout variety has a compact spike and a rather coarse grain. As in the Coast barley, the beard sometimes is not entirely removed in thrashing. It matures about the same time as the White Smyrna. The average yield of the Mariout is slightly lower than that of the Coast variety.

The leading naked varieties of barley at Moccasin are the Nepal and Himalaya. The 5-year average yield of the Himalaya, as shown in Table XXI, is slightly greater than that of the Nepal. In the 7-year averages, however (Table XXI), the Nepal exceeds the Himalaya by 2.3 bushels. The Nepal is a 6-rowed, naked, hooded variety, sometimes called the White Hull-less. The kernels are of medium size and amber in color. The Himalaya is a 6-rowed, naked, bearded barley, with bluish kernels. Because of the absence of beards the Nepal is commonly grown in preference to the Himalaya. The heads of the Nepal have a tendency to break off when ripe, and the variety also lodges to some extent in wet years. The broad leaves, coarse straw, and absence of beards make this variety a popular one for hay production.

The average yield of the Nepal variety at Moccasin in the five years is 30.2 bushels, 20 bushels less than that of the White Smyrna during

the same period. The weight per bushel of the naked varieties is 60 pounds, while that of the hulled varieties is 48 pounds, so that the actual difference in yield is less than would appear from these figures. The yield of the Nepal in pounds is about three-fourths that of the White Smyrna variety.

The average dates of sowing, heading, and ripening, and the average height, yield, and weight per bushel of these six varieties for five years (1910, 1911, and 1913 to 1915) are given in Table XXII. These average yields are shown graphically in figure 14.



FIG. 14.—Diagram showing the average yields of the leading varieties of barley at the Judith Basin substation for five years, 1910, 1911, and 1913 to 1915, inclusive.

TABLE XXII.—Average dates of seeding, heading, and ripening, days from seeding to maturity, height, yield of straw and of grain, and weight per bushel of six leading varieties of barley at the Judith Basin substation, Moccasin, Mont., during five years, 1910, 1911, and 1913 to 1915, inclusive.

Group and variety.	C. I. No.	Average date—			Seed- ing to ma- turity.	Height.	Average yield per acre.			Weight per bushel.
		Sown.	Headed.	Ripe.			Grain.	Grain.	Straw.	
Two-rowed hulled:					<i>Days.</i>	<i>Inches.</i>	<i>Bush.</i>	<i>Lbs.</i>	<i>Lbs.</i>	<i>Lbs.</i>
White Smyrna.	195	Apr. 18	July 6	Aug. 4	108	29	52.9	2,540	1,996	48.2
Hannchen.	531	...do...	July 11	Aug. 6	110	32	47.9	2,299	2,456	48.4
Six-rowed hulled:										
Coast.	690	...do...	July 6	Aug. 5	109	32	48.0	2,304	1,995	46.0
Mariout.	261	...do...	July 5	...do...	109	31	46.8	2,246	1,524	46.2
Six-rowed naked:										
Himalaya.	620	...do...	July 6	...do...	109	31	31.9	1,914	1,904	61.0
Nepal.	595	...do...	July 8	...do...	109	32.6	30.2	1,812	1,850	61.0

EXPERIMENTS WITH FLAX.

Experiments with flax were not started until 1911. Flax is not grown to any great extent in the Judith Basin. The crop is important in the eastern part of the State, although there is not as much flax raised now as there was several years ago. It is usually grown in newly settled districts, as it is considered a good crop to grow on sod land.

The experiments at Moccasin have included tests of both seed and fiber flax. Quite a number of fiber varieties were tested in 1911, but as they were of little value for seed production they were discarded.

VARIETAL EXPERIMENTS IN FIELD PLATS.

Nineteen varieties of flax have been grown in the varietal test. Of these, 12 belong to the European seed, 2 to the Smyrna seed, 4 to the European short fiber, and 2 to the European textile fiber group.

In 1911, 14 varieties were grown in twentieth-acre plats. The land used had been cropped to barley in 1909 and 1910. It was spring plowed in 1911 and the seed bed was in good tilth when the varieties were seeded on May 15. The dry weather in July caused the flax to begin to ripen early and the heavy rains in August started a second growth. This made the flax late in maturing and reduced the yields.

In 1912, 17 varieties were grown. These were seeded on May 14 in twentieth-acre plats on land that had been cropped to winter wheat the year before. Flax was the only spring grain that produced any seed in 1912, the others being destroyed by hail. The



FIG. 15.—Varietal test plats of flax at the Judith Basin substation, 1915. (From a photograph lent by the Office of Exhibits, U. S. Department of Agriculture.)

hail came when the flax was in full bloom. While it undoubtedly reduced the yields, the plants made a second growth and produced a fairly good crop. In 1913 the flax was grown in tenth-acre plats on fallow ground. The yields that year were quite satisfactory. In 1914 and 1915 the flax varieties were grown on fallow ground in replicated fiftieth-acre plats. A view of the varietal test plats in 1915 is shown in figure 15.

The yields in 1914 were reduced by a disease known as canker. This disease attacks the young plant just above the cotyledons and apparently stops its growth until it puts out basal branches below the injured part. The growth is then normal, but the time required to produce these branches makes the plants late in maturing. The seed is produced on these branches, which take the place of the central stem.

The annual and average yields in bushels per acre of the varieties of flax that have been grown in field plats at Moccasin in the five years, 1911 to 1915, are given in Table XXIII.

TABLE XXIII.—*Annual and average yields of 19 varieties of flax grown in plats at the Judith Basin substation, Moccasin, Mont., in periods of varying length, 1911 to 1915, inclusive.*

Group and variety.	C. I. No.	Yield per acre (bushels).						
		1911	1912	1913	1914	1915	Average.	
							1911 to 1915	1914 to 1915
European seed:								
Russian (N. Dak. No. 155).....	19	19.3	13.3	16.6	13.0	22.8	17.0	17.9
Russian (N. Dak. No. 155).....	17	14.6	11.7	15.6	12.5	18.9	14.7	15.6
Select Russian (N. Dak. No. 608).....	1	17.1	10.0	14.0	12.0	19.3	14.5	15.8
Select Russian (N. Dak. No. 609).....	45	.....	.....	.....	13.6	19.0	.....	16.3
Select Russian (N. Dak. No. 1215).....	3	15.7	13.0	18.0	12.8	19.5	15.8	16.2
Montana Common.....	6	15.4	10.0	9.0	13.2	20.0	13.5	16.6
Select Riga (N. Dak. No. 1214).....	2	18.3	9.0	19.6	13.0	19.1	15.8	16.1
Stepan (N. Dak. No. 1340).....	5	15.0	11.3	16.8	12.1	19.9	15.0	16.0
North Dakota Resistant No. 52.....	8	16.0	6.3	14.0	11.8	19.5	13.7	15.7
North Dakota No. 1221.....	16	15.7	12.7	16.4	13.2	19.9	15.6	16.5
Fargo Common (N. Dak. No. 1133).....	18	14.6	10.1	19.2	13.2	19.5	15.4	16.4
Smyrna seed:								
Smyrna.....	30	.....	.....	.....	14.8	19.2	.....	17.0
Turkish.....	7	6.9	4.8	12.0	9.0	15.1	9.5	12.0
European short fiber:								
Kazan (N. Dak. No. 1329).....	4	9.2	10.0	17.5	13.2	18.9	13.7	16.0
Idaho Common.....	15	.....	.....	.....	13.0	19.4	.....	16.2
North Dakota Resistant No. 114.....	13	.....	.....	.....	12.3	16.8	.....	14.6
Primost (Minn. No. 25).....	12	11.0	10.3	17.5	12.8	19.1	14.1	16.0
European textile fiber:								
Blue Blossom.....	22	9.6	8.3	15.3	12.1	17.5	10.5	14.6
Pskof.....	32	.....	.....	.....	10.0	8.0	.....	9.0

LEADING VARIETIES.

Table XXIII shows that in both the 5-year and 2-year averages the varieties of the European seed-flax group yield more than those of the other groups. The five highest yielding strains for the 5-year period, C. I. Nos. 19, 3, 2, 16, and 18, all belong to the seed-flax group. The Russian, C. I. No. 19 (N. Dak. No. 155), is the highest yielder and the Select Russian, C. I. No. 3 (N. Dak. No. 1213), a selection from North Dakota No. 155, is second. C. I. Nos. 17 and 19 are both Russian (N. Dak. No. 155), but were received at Moccasin through different sources. C. I. No. 19 has given better results than C. I. No. 17. North Dakota No. 155 is a bulk lot of seed of Russian flax obtained by the North Dakota Agricultural Experiment Station in 1898. It has been grown and distributed since that time. C. I. Nos. 1, 3, and 45 are selections from this variety developed in the nursery at the North Dakota station.

C. I. Nos. 2 and 16 were both developed through selection from common flax varieties at the North Dakota station, while C. I. No. 18 was a bulk lot of seed obtained by that station in 1901 from a seed house at Fargo, N. Dak. All of these strains are of the Russian seed type of flax, and with the exception of some variations in coarseness of stem and earliness are much alike.

North Dakota Resistant No. 52, a wilt-resistant flax of the seed type, has not yielded as well as the Russian.

The Smyrna flax (C. I. No. 30), which ranks second in average yield for the two years it has been grown, was imported from Smyrna, Turkey, by the United States Department of Agriculture, in 1913. This variety has shorter straw and more numerous basal branches than the European seed flaxes. From results obtained elsewhere it seems to be better able to withstand unfavorable hot, dry weather than other varieties in the test.

North Dakota Resistant No. 114 and Primost (Minn. No. 25), both of which belong to the short-fiber group, did not produce yields which compare favorably with those of the European seed flaxes. These varieties would probably give better results in regions where flax canker is more serious than at Moccasin.

The textile fiber type of flax is of no value for seed production in Montana.

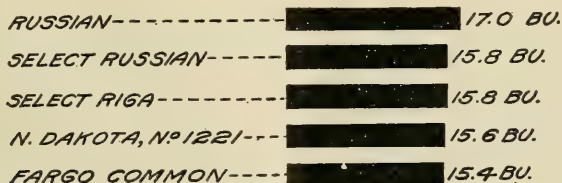


FIG. 16.—Diagram showing the average yields (in bushels per acre) of the leading varieties of flax at the Judith Basin substation for the five years, 1911 to 1915, inclusive.

Table XXIV gives the average dates of seeding, heading, and ripening, the yields of straw and grain, and the weight per bushel of the five leading varieties of flax in the five years 1911 to 1915, inclusive. The average yields of these varieties are shown graphically in figure 16.

TABLE XXIV.—Average dates of seeding, heading, and ripening, days from seeding to maturity, yield of grain and straw, and weight per bushel of five leading flax varieties at the Judith Basin substation, Moccasin, Mont., in the five years, 1911 to 1915, inclusive.

Group and variety.	C. I. No.	Average date—			Seeding to maturity.	Height.	Average yield per acre.		Weight per bushel. ¹
		Seeded.	Headed.	Ripe.			Grain.	Straw.	
European seed flax:					Days.	Inches.	Bushels.	Pounds.	Pounds.
Russian (N. Dak. No. 155).....	19	May 8	July 19	Aug. 28	112	23.0	17.0	1,654	56.0
Select Russian (N. Dak. No. 1215).....	3	...do...	July 20	...do....	112	23.0	15.8	1,610	56.0
Select Riga (N. Dak. No. 1214).....	2	...do...	...do....	...do....	112	22.8	15.8	1,456	55.7
North Dakota No. 1221.....	16	...do...	...do....	...do....	112	22.6	15.6	1,440	55.7
Fargo Common (N. Dak. No. 1133).....	18	...do...	...do....	...do....	112	22.0	15.4	1,386	55.7

¹ Average for four years, 1912 to 1915, inclusive.

VARIETAL EXPERIMENTS IN NURSERY ROWS.

Nursery work with flax was not started until 1914, when 50 varieties and strains were tested. These varieties were grown in fiftieth-acre and hundredth-acre plats and in 8-rod rows. Most of them were recent importations from Europe which were grown in this country for the first time in 1914.

In 1915 the flax nursery was increased. In addition to the tests in fiftieth-acre plats and 8-rod rows, 204 selections were grown in head rows. Some of the head rows were selections from the most promising varieties and some were selections from a natural hybrid. A view of the flax nursery in 1915 is shown in figure 17.

Several promising varieties which are now being grown in the nursery will soon be added to the varietal test.



FIG. 17.—The flax nursery at the Judith Basin substation, 1915. (From a photograph lent by the Office of Exhibits, U. S. Department of Agriculture.)

DATE-OF-SEEDING EXPERIMENT.

There appears to be some question as to the proper date on which to sow flax. The impression seems to exist in some sections that flax should be sown later than the spring grains. The date-of-seeding test at Moccasin has not been conducted long enough to justify drawing definite conclusions from it. The results seem to indicate, however, that early seeding is the best. In 1915 the highest yield was obtained from the plat seeded on April 9. While there was some freezing weather after this date it apparently did no harm to the flax. The tests at Moccasin show that flax should be sown not later than May 1, as seedings made after that date will not produce as good yields.

RATE-OF-SEEDING EXPERIMENT.

A rate-of-seeding test with flax is being conducted at Moccasin, but, like the date-of-seeding test, it has not been continued long enough to justify any definite conclusions. During the last three years the varietal plats have been seeded at the rate of 18 pounds

per acre. Very satisfactory stands and yields have been obtained from this rate, although the rate-of-seeding experiment seems to indicate that a little heavier seeding would give better results.

COMPARISON OF THE LEADING VARIETIES OF CEREALS.

Table XXV gives the annual and average yields (in pounds per acre) of the leading varieties of each of the cereals at Moccasin for five years, 1910, 1911, and 1913 to 1915, inclusive. This table is presented so that a comparison may be made of the actual yield of grain of each of the cereals. It will be seen from Table XXV that on the average the White Smyrna barley produces more pounds of grain per acre than any of the other cereals. The Kharkof winter wheat is second and the Sixty-Day oats third in the number of pounds of grain produced per acre.

The average farm value per acre of each of the crops is also given in Table XXV. To obtain this value the annual yield of each crop was multiplied by the farm price per bushel in Montana on December 1 of that year, and the annual values for the five years were then averaged. Winter wheat leads in value per acre, with the White Smyrna barley second and flax third.

TABLE XXV.—*Annual and average yields and average farm value of the leading variety of each of the cereals grown at the Judith Basin substation, Moccasin, Mont., for five years 1910, 1911, and 1913 to 1915, inclusive.*

Crop and variety.	C. I. No.	Yield per acre (pounds).						Acre value of crop ^a
		1910	1911	1913	1914	1915	Average.	
Kharkof winter wheat.....	1,583	2,880	2,478	1,866	1,470	2,964	2,331	\$31.08
Pelissier spring wheat.....	1,584	630	1,698	1,920	1,590	2,530	1,673	21.58
Sixty-Day oat.....	165	1,056	2,278	2,409	1,888	2,998	2,126	23.70
White Smyrna barley.....	195	590	2,490	3,360	2,400	3,854	2,540	28.42
Nepal barley.....	595	984	1,800	2,220	1,542	2,508	1,810	18.24
Russian flax.....	19	-----	1,070	930	728	1,282	1,002	^a 27.09

^a Average for four years, 1911 and 1913 to 1915.

EXPERIMENTS WITH MINOR CEREALS.

Twenty-seven varieties of proso have been tested at Moccasin at some time during the past eight years. While most of the varieties tried will mature seed in a favorable year, the yield is small and in some years no seed is produced. For this reason the crop is not recommended for the Judith Basin.

Some early varieties of brown kaoliang and broom corn were tried for three years. Owing to the short season and cool nights none of them matured seed.

Emmer and spelt have also been tried, but are not as promising as some of the other grain crops.

SUMMARY.

Cooperative experiments with cereals at the Judith Basin substation, Moccasin, Mont., have been conducted during eight years, 1908 to 1915, inclusive.

The Judith Basin substation is located in the west-central part of Fergus County, in central Montana. The altitude is 4,300 feet.

The yields obtained at Moccasin are not representative of all the dry-land area, but the comparative results obtained are believed to be applicable in general to all the dry-farming area of Montana.

The annual average precipitation at Moccasin for 18 years, 1898 to 1915, inclusive, is 16.66 inches. The average seasonal rainfall (April to July, inclusive) for the same years is 9.41 inches.

The soil at Moccasin on which the cereal varieties have been tested is a dark clay loam of limestone origin.

On the average, satisfactory yields are obtained from winter and spring wheat, spring oats, barley, and flax.

The best winter wheats are the Kharkof and Turkey. These belong to the Crimean group of hard winter wheats.

The best rate to sow winter wheat is 3 pecks per acre. The best date to sow is from August 10 to September 10.

The highest yields of spring wheats have been obtained from varieties of durum wheat. Of these, the Pelissier has been the best. Of the common spring wheats the best variety to grow appears to be the Marquis.

Spring wheats are seeded at the rate of 4 pecks per acre.

The best results are obtained from sowing all spring wheat, oats, and barley as early in the spring as soil and climatic conditions will permit.

The highest average yield of oats was obtained from the Sixty-Day variety. This variety averaged about 16 bushels per acre more than later maturing varieties.

The best rate of seeding for the small-kerneled early varieties of oats, such as the Sixty-Day, is about 4 pecks per acre.

The White Smyrna barley, a 2-rowed bearded hulled variety, has given the highest average yield.

The hulled varieties of barley are seeded at the rate of 5 pecks and the naked varieties at the rate of 4 pecks per acre.

The highest yield of flax in a 5-year test was obtained from the Russian variety.

It is probable that the best results will be obtained if flax is sown early, between April 15 and May 1. The best rate seems to be from 20 to 25 pounds per acre.

In pounds per acre, the average yield of the White Smyrna barley is greater than that of the best variety of any of the other cereal

crops. The Kharkof winter wheat is second in yield, followed by the Sixty-Day oats, the Nepal naked barley, the Pelissier spring wheat, and the Russian flax.

In the value per acre based on the farm price on December 1 of each year, the Kharkof winter wheat leads, followed by the White Smyrna barley, the Russian flax, the Sixty-Day oats, the Pelissier durum spring wheat, and the Nepal naked barley.

Emmer and spelt do not give as good yields as barley and oats.

Proso millet has been tried, but is not a promising crop.

Early varieties of brown kaoliang and broom corn have been tested, but do not mature seed.

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UNITED STATES DEPARTMENT OF AGRICULTURE



BULLETIN No. 399

Contribution from the Bureau of Plant Industry
WM. A. TAYLOR, Chief



Washington, D. C.

December 16, 1916

THE PRODUCTION OF SWEET-ORANGE OIL AND A
NEW MACHINE FOR PEELING CITRUS FRUITS.

POSSIBILITY OF THE COMMERCIAL PRODUCTION OF SWEET-
ORANGE OIL FROM WASTE ORANGES.

By S. C. HOOD, *Scientific Assistant*, and G. A. RUSSELL, *Expert*, of Office Drug-Plant
and Poisonous-Plant Investigations.

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INTRODUCTION.

The oil extracted from the fresh peel of the sweet orange has long been an important article of commerce in the United States and Europe. It is extensively used in the manufacture of flavoring extracts, perfumes, and soaps, and to a small extent in the drug trade, the oil being official in the ninth decennial revision of the United States Pharmacopœia. Until recently, this product was secured wholly from Italy, Sicily, and other parts of southern Europe. Since the year 1911, however, a considerable industry has grown up in the West Indies, and a portion of the annual requirement in the United States is now supplied from that region.

The methods of extracting sweet-orange oil are similar in all countries wherever practiced. The fruit is peeled by hand, either by cutting it in half crosswise and scooping out the pulp or by stripping off the peel in three longitudinal pieces. The peel thus secured is inverted and pressed over a small sponge. By this means the oil

NOTE.—This bulletin is of interest to growers of oranges generally.

cells of the outer part of the peel are ruptured and the mixture of oil and other liquids is forced out in a fine spray. After the sponge has become saturated, the contents are squeezed into a bowl, and the oil is eventually drained off the accumulated liquid. From time to time various machine methods have been tried, but apparently none of them has proved satisfactory. Furthermore, when the peel is pressed in quantity by machinery an emulsion is formed from which it is very difficult to separate the oil. Accordingly, almost the entire output of sweet-orange oil is extracted by the hand-pressing method.

IMPORTANCE OF THE INDUSTRY.

Complete figures on the total world production of sweet-orange oil are not available, but the annual exports from Italy and Sicily, which represent a large portion of the world's production, have been compiled from various sources and are given in Table I.

TABLE I.—*Export of sweet-orange oil from Italy and Sicily for the years 1906 to 1913, inclusive.*

Year.	Quantity.	Value.	Year.	Quantity.	Value.
	<i>Pounds.</i>			<i>Pounds.</i>	
1906.....	301,455	\$666,984	1910.....	285,357	\$415,065
1907.....	357,749	782,972	1911.....	90,078	131,021
1908.....	381,980	735,683	1912.....	118,366	193,691
1909.....	498,705	770,725	1913.....	105,826	202,033

It will be seen from Table I that in 1911 there was a marked decrease in the exports and that in the two following years the quantity exported was much lower than in the six preceding years. This decline is due in part to a small crop of oranges in Italy in 1911, in part to a heavy import tax levied in this country, and in part to the activity of producers in the West Indies, which region is now producing a quantity nearly sufficient to meet the American as well as the British demand.

The imports of sweet-orange oil entered for consumption in the United States are shown in Table II.

TABLE II.—*Imports of sweet-orange oil into the United States from all sources for the years 1900 to 1914, inclusive.*

[Compiled from Commerce and Navigation of the United States.]

Year.	Quantity.	Value.	Year.	Quantity.	Value.	Year.	Quantity.	Value.
	<i>Pounds.</i>			<i>Pounds.</i>			<i>Pounds.</i>	
1900.....	57,069	\$95,405	1905.....	92,077	\$143,555	1910.....	46,814	\$65,488
1901.....	72,218	109,832	1906.....	74,535	122,634	1911.....	73,786	100,115
1902.....	79,160	104,159	1907.....	112,834	199,027	1912.....	97,065	168,831
1903.....	77,138	107,808	1908.....	71,224	165,982	1913.....	77,797	155,299
1904.....	74,816	109,478	1909.....	87,591	151,861	1914.....	104,597	222,118

The price of sweet-orange oil is subject to considerable variation, the extent of which is influenced both by the relative abundance of the

orange crop in the regions where this oil is produced and also by market speculation. Table III gives the prices paid by jobbers, in January, June, and December, for a period of 10 years for Italian hand-pressed oil from Messina, Italy, delivered in New York City.¹

TABLE III.—*Prices of Italian hand-pressed sweet-orange oil, f. o. b. New York, for the years 1905 to 1914, inclusive.*

Year.	Price per pound.			Year.	Price per pound.		
	January.	June.	December.		January.	June.	December.
1905.....	\$1.521	\$1.744	\$1.764	1910.....	\$1.338	\$1.379	\$1.379
1906.....	1.974	1.947	1.947	1911.....	1.541	1.541	1.906
1907.....	1.987	2.068	2.109	1912.....	1.886	1.926	2.271
1908.....	2.149	1.501	1.399	1913.....	2.616	3.569	3.042
1909.....	1.886	1.399	1.379	1914.....	2.636	1.947	1.318

Table IV gives the wholesale market prices for the Italian hand-pressed oil for a period of 10 years, as quoted in the Oil, Paint, and Drug Reporter. These figures represent the high and low prices quoted at the middle of each month. From Tables III and IV, therefore, can be noted the difference between the prices paid the producer by the jobber and the prices asked for the oil in the wholesale market.

TABLE IV.—*Monthly market quotations for Italian hand-pressed sweet-orange oil for the years 1906 to 1915, inclusive.*

Month and price.	Year.									
	1906	1907	1908	1909	1910	1911	1912	1913	1914	1915
January:										
Low.....	\$2.00	\$2.10	\$2.45	\$2.50	\$2.20	\$2.25	\$2.40	\$2.70	\$3.00	\$1.60
High.....	2.25	2.30	2.60	3.00	2.25	2.30	2.50	3.00	3.25	1.75
February:										
Low.....	2.10	2.10	2.40	2.10	2.20	2.25	2.45	2.90	2.75	1.55
High.....	2.25	2.30	2.60	2.25	2.40	2.30	2.60	3.25	3.00	1.75
March:										
Low.....	2.20	2.15	2.25	2.00	2.25	2.25	2.55	3.00	2.65	1.50
High.....	2.35	2.25	2.50	2.25	2.50	2.30	2.65	3.25	2.80	1.60
April:										
Low.....	2.10	2.20	2.20	1.90	2.25	2.20	2.45	2.90	2.60	1.55
High.....	2.25	2.25	2.40	2.10	2.50	2.25	2.60	3.10	2.80	1.60
May:										
Low.....	2.10	2.10	2.10	1.80	2.25	2.20	2.45	3.00	2.30	1.65
High.....	2.25	2.25	2.25	2.00	2.50	2.30	2.60	3.15	2.35	1.85
June:										
Low.....	2.10	2.10	1.80	1.75	2.20	2.35	2.45	3.25	2.20	1.75
High.....	2.25	2.25	2.00	1.90	2.50	2.35	2.50	3.50	2.40	2.00
July:										
Low.....	2.10	2.40	1.70	1.80	2.20	2.35	2.45	3.50	2.15	2.00
High.....	2.25	2.50	1.90	2.00	2.50	2.40	2.60	3.75	2.30	2.25
August:										
Low.....	2.20	2.25	1.65	2.00	2.20	2.45	2.45	3.75	4.00	1.85
High.....	2.35	2.35	1.90	2.25	2.50	2.60	2.60	4.00	4.25	2.00
September:										
Low.....	2.20	2.25	1.70	1.90	2.15	2.55	2.60	3.90	3.25	1.80
High.....	2.35	2.35	1.90	2.10	2.25	2.70	2.70	4.25	3.75	2.15
October:										
Low.....	2.20	2.30	1.60	1.90	2.15	2.50	2.60	4.00	1.80	1.75
High.....	2.35	2.50	1.90	2.10	2.25	2.60	2.75	4.25	2.00	2.00
November:										
Low.....	2.20	2.45	1.65	2.00	2.15	2.40	2.60	3.40	1.60	1.65
High.....	2.35	2.60	1.90	2.10	2.25	2.60	2.70	3.50	1.75	1.75
December:										
Low.....	2.15	2.40	1.65	2.05	2.20	2.40	2.65	3.20	1.50	1.85
High.....	2.20	2.60	1.90	2.20	2.25	2.50	2.75	3.40	1.75	1.90

¹ Haven, J. F. Essential oils in Italy. *In Amer. Perfumer*, v. 10, no. 7, p. 175. 1915.

MATERIAL AVAILABLE FOR THE PRODUCTION OF ORANGE OIL.

In the commercial production of oranges there is always a greater or less quantity of waste fruit. Oranges which are defective in shape or which show even slight blemishes on the skin are rejected and thrown out on the cull heap (fig. 1). The quantity thus rejected varies according to the season, to the variety of fruit, and to the care which is given to the production of the crop, but even under the most favorable conditions it is considerable. With the increasing tendency to grade the fruit more closely and to better the market conditions, the proportion of culls will doubtless increase rather than decrease.

A considerable loss results also from the dropping of the fruit in the groves throughout the winter months. Certain varieties show



FIG. 1.—Piles of cull oranges in a grove.

this tendency regularly, although all varieties have a tendency to drop the fruit when held for market advances under unfavorable climatic conditions.

In addition to these sources of available material it is possible to obtain a quantity of low-grade fruit. At present this low-grade fruit, packed in so-called "plain wraps," is sometimes shipped to near-by markets for immediate consumption. The returns are exceedingly small, especially in years when the crop is abundant. It is believed, however, that with greater attention to marketing conditions this inferior fruit can be more profitably utilized in the manufacture of by-products and thus open a wider field for the better grades. At the present time there is without doubt enough low-grade fruit available to make possible the extraction of a quantity of orange oil sufficient to supply a considerable portion of the domestic demand.

METHODS OF EXTRACTION.

For use in these experiments a new type of peeling machine¹ was devised which removes the peel and at the same time ruptures the oil cells. As the peel comes from the machine it is in a finely divided condition (fig. 2) and the oil cells are practically all opened. The oil being thus released from the cells is more or less absorbed by the spongy remainder of the peel. The outer portion of the peel, in which the oil cells are contained, is of course the first to be removed by the machine, and experiments have shown that the peel removed by the first third of the length of the grating drum contains approximately 76 per cent of the oil; that removed by the second third contains about 23 per cent, while that from the last third has less than 1 per cent of oil. For this reason it was found economical to discard the peel removed by the last third of the grating drum and to employ only that removed by the first two thirds.



FIG. 2.—Oranges before and after peeling and the finely divided peel.

In order to recover the oil, distillation by both steam and vacuum was employed. It was found, however, that the oil obtained by means of steam distillation was not of good quality. It was either water white or pale yellow in color and possessed to only a very slight degree the valuable odor-bearing and flavoring constituents desirable in orange oil.

For distilling under vacuum a special type of apparatus is necessary (fig. 3). This apparatus consists of a copper retort connected with a condenser and so arranged that nearly all the air within the apparatus can be removed by means of a vacuum pump. Distillation is then accomplished either by means of heat from the steam jacket or by direct admission of steam into the retort.

The peel is first mixed with water to form a fairly thin paste. This mixture is then placed in the retort, the cover clamped down, and all connections made air-tight. The vacuum pump is next started and the air exhausted from the apparatus. As the air pressure becomes less the pressure can be read by means of a gauge

¹ A detailed description of this machine, covered by United States Letters Patent No. 1186317, dedicated to the public, is given in the second part of this bulletin, pages 13 to 19.

attached to the distilling apparatus. When the gauge indicates sufficient diminution in the pressure, steam is admitted into the jacket of the retort. The thin mixture of water and peel begins to boil almost immediately, and the water vapors passing into the condenser carry the oil with them. Here the vapors are condensed and the distillate is collected in the receiver. The oil being lighter than water floats on the surface and can easily be separated. The peel is exhausted in about 30 minutes. Steam can also be admitted directly into the retort and the oil extracted under diminished pressure by direct steam. The oil obtained by vacuum distillation was light lemon yellow in color and possessed a pleasing orange odor and

the characteristic aromatic orange taste.

The oil obtained by direct steam distillation is not of as good quality as that obtained when the heat is applied by means of the jacket. The best results, however, were obtained when both jacket heat and direct steam were used simultaneously. The oil obtained was macerated with 20 per cent of its weight of fresh unextracted peel and then filtered. Thus treated, the oil had a lemon-yellow color with a slight tinge of brown. It

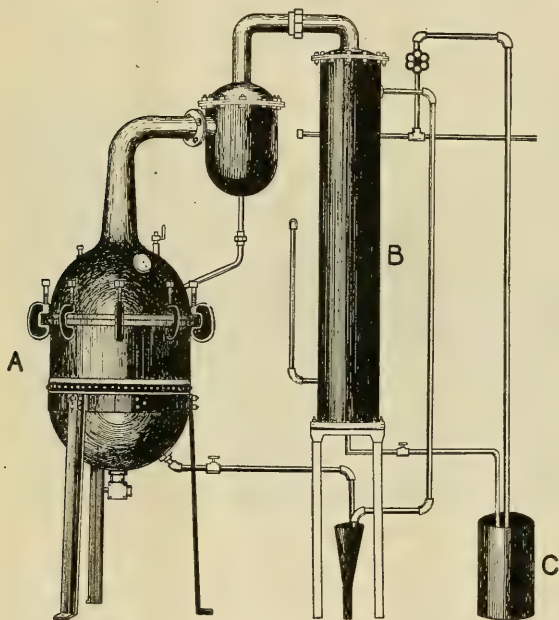


FIG. 3.—Experimental vacuum still used in extracting orange oil: A, Still; B, condenser; C, receiver.

had an excellent orange odor and the characteristic aromatic orange taste. Apparently the odor-bearing and flavoring constituents are all present and by the method described a fair grade of orange oil can be prepared.

PRESSED OIL.

Pressed orange oil is generally understood to mean the oil which is pressed from the peel by hand. Where labor is cheap such a method of extraction is economically possible, but where labor is relatively costly this method can not be used. Accordingly, methods were worked out for applying heavy pressure without any great outlay of money for hydraulic presses.

In some preliminary experiments it was noted that when a portion of the vacuum-distilled oil was macerated with unpressed peel for several hours the loss in the volume of the oil recovered was in some instances as high as 10 per cent. Some oil had been absorbed by the peel, although the peel employed contained all its original content of oil. When pressure was applied to this macerated peel all the original oil could be pressed out. A portion of the peel pressed before maceration yielded about 95 per cent of its original oil content. When, however, the press cake was distilled with water and the oil thus produced used to macerate the next lot of peel to be pressed, the yield of oil obtained was approximately the original content of the peel. With these facts in mind, the following method was devised for extracting sweet-orange oil by pressure:

An inexpensive press (fig. 4) was employed in the experimental work. This press consists of a heavy wooden frame, a wooden drum fitted with a perforated brass cylinder, and a heavy screw for applying pressure. About 20 pounds of the finely ground peel from the first two-thirds of the grating drum was placed in a canvas sack made of 10-ounce duck and the sack placed in the wooden drum. Pressure was then applied by means of the heavy screw. Before pressing, the peel was thoroughly mixed with approximately one-half its weight of water and the whole heated to not over 90° C. The oil and water pressed out were collected in a large container, where the oil came to the top and the water was easily removed.

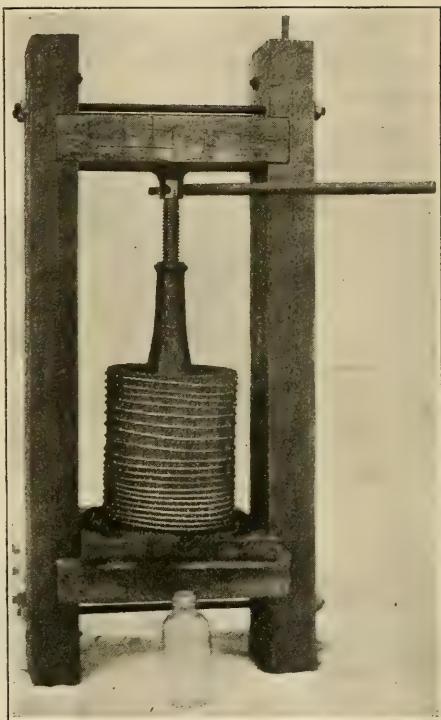


FIG. 4.—Experimental press used in extracting orange oil.

The press cake was then thrown into a still (fig. 5, *a*) and distilled with water. A small quantity of oil was thus secured which was added to the next lot of peel and the mixture allowed to macerate for a short time. After pressing several lots the mixture of oil and water was placed in a separatory funnel (fig. 5, *d*) and all the water possible was removed.

The oil thus obtained formed a thick emulsion with a portion of the water. This emulsification was brought about by means of a gumlike substance which was pressed from the ground peel. The mixture thus formed was found to resist all the regular methods for breaking emulsions. Centrifuging did not throw out the oil, but,

on the contrary, more completely emulsified it. Treatment with kieselguhr (infusorial earth) and subsequent filtering under difference in pressure yielded a clear oil, but the process was entirely too slow in operation. After several experiments the following method was found to work very satisfactorily.

All the water possible was removed with a separatory funnel, and the emulsion warmed on a water bath to not over 90° C. To this was added one-tenth its volume of a hot solution containing 2 per cent of gelatin and the whole thoroughly mixed. To the warm mixture was added one-fourth its volume of a hot solution containing approximately 10 per cent of tannin. The emulsifying agent was thus brought into a state of coagulation, and the oil was released. The mass was

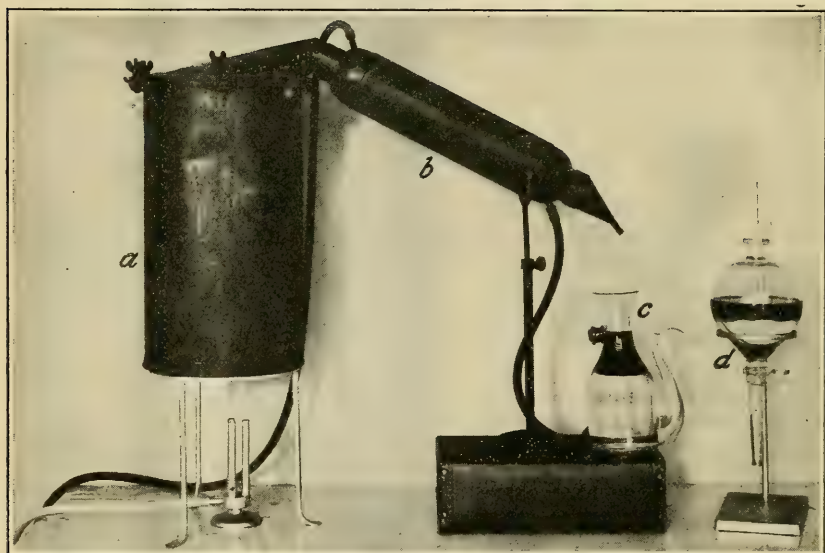


FIG. 5.—Experimental still used in extracting orange oil: *a*, Still; *b*, condenser; *c*, receiver; *d*, separatory funnel.

now thrown into a sack made of heavy Canton flannel and again pressed. The oil and water thus pressed out were separated by means of the separatory funnel, and the oil dried with quicklime and filtered. The filtered oil constitutes the marketable product.

When the method was thus proved to be practicable, a cheap and abundant supply of tannin was sought. This was found in the rhizome of the common saw palmetto, which contains approximately 7.58 per cent of tannin.¹ A portion of this rhizome was boiled with water in a copper vessel for several hours and the liquor then strained off. Ten pounds of the fresh rhizome was found to yield a supply of tannin solution sufficient to treat the emulsion from at least a ton of oranges.

¹ Trimble, H. The tannins of the palmettos. *In* Gard. and Forest, v. 9, no. 428, p. 182-183. 1896.

COMPARISON OF THE VARIOUS OILS.

In order that the oils obtained by the processes outlined might be compared with commercial imported Italian hand-pressed oil, a sample of the latter was purchased in the open market, and the results of the comparison are shown in Table V.

TABLE V.—*Comparison of the oils obtained by vacuum distillation and by pressing with a commercial sample of hand-pressed imported oil.*

Description of oil.	Color.	Odor.	Taste.	Specific gravity, at 25° C.	Specific rotation ($[\alpha]_D$), at 25° C.	Evaporation residue.	Total absorption by sodium bisulphite.
Italian hand pressed.	Lemon yellow.	Characteristic orange.	Characteristic, aromatic; no bitterness.	0.8415	115° 6'	<i>Per cent.</i> 1.73	<i>Per cent.</i> 2.92
Florida: Vacuum distilled.	Lemon yellow, with slight brown tinge.	do.....	do.....	.8423	115° 18'	2.10	2.66
Machine pressed.	Reddish yellow.	Characteristic orange; excellent fruity aroma.	do.....	.8445	109° 36'	2.90	4.00

Sweet-orange oil is graded on the market according to its color, odor, taste, specific gravity, and angle of rotation. The ninth decennial revision of the United States Pharmacopœia describes orange oil as a yellow liquid, having the characteristic odor and taste of orange peel. The specific gravity, at 25° C., lies between 0.842 and 0.846; the optical rotation is not less than +94° in a 100-mm. tube at 25° C.

Table V reveals some interesting comparisons. The color of the pressed oil as given is reddish yellow, due entirely to coloring matter which was forced out by the heavy pressure used in extracting the oil. This color in no way interferes with the commercial uses of the oil and is not detrimental to its sale. The odor, on comparison, shows that the pressed oil is somewhat superior to the vacuum-distilled oil and also to that of the commercial sample. It possesses the characteristic odor of orange peel, and in addition has a fine, fruity, very agreeable aroma. In all the samples, the oils possessed a fine, characteristic, aromatic taste. The specific gravity of the sample bought in the open market is slightly below that stated in the Pharmacopœia as the minimum limit. The vacuum-distilled and pressed oils are safely within the limits. The angles of rotation of the commercial sample and the vacuum-distilled oils agree very closely; that of the pressed oil is somewhat lower, indicating that this sample probably contains more of the valuable optically inactive constituents and less of the optically active limonin. The residue

on evaporation, which may be taken as a partial measure of the freshness of the sample and also as a partial measure of the valuable constituents, varies to a considerable extent. This is to be expected, since the oils are prepared under such widely varying conditions. In a commercial examination of sweet-orange oil, Schimmel & Co. have placed the residue on evaporation at 2 to 4 per cent.¹ Often the residue on evaporation falls below 2 per cent, as in the sample of oil purchased in the open market. Rarely does it exceed 4 per cent, and when it does the conclusion may be drawn that the oil is either quite old or it is adulterated. Both the oils extracted by the methods outlined in this bulletin fall within the limits fixed by Schimmel & Co., the oil obtained by pressure having the highest evaporation residue. This high percentage is due to the larger quantities of the waxes and nonvolatile constituents which were pressed out and probably indicates a better grade of oil.

The quantity of oil absorbed by the sodium-bisulphite solution is of special interest. Although the tabulated results do not represent the true percentage of aldehydes present in these oils, they do serve as a comparative estimate of the commercial value. Of the three samples of oil, that which was obtained by heavy pressure is by far the best. The hand-pressed oil ranks second and the vacuum-distilled oil third. The last two, however, agree closely in the percentage of oil absorbed.

The results of the comparison of the various oils indicate that the oils prepared by the methods described in this bulletin are equal, if not superior, to the hand-pressed oil obtained abroad, and of the three samples the one obtained by heavy pressure is the best.

COMMERCIAL POSSIBILITIES.

From the results of numerous experiments and from its favorable acceptance by the trade after an examination of the oil, it is recommended that only the pressed oil be produced. The necessary outlay in money for equipment is small, and the product is of an extremely high grade. In addition to the peeling machine, the apparatus and material required are as follows:

Pressing device (fig. 4).
Still (fig. 5).
Separatory funnels.
Glass or tin funnels.

Filter papers.
Tin containers.
Unslaked lime.

The pressing device as illustrated is of the simplest type. A press equally efficient and of more rapid manipulation can readily be constructed by any mechanic. The drum should not exceed 12 inches inside diameter and should be about 16 inches high. It should be

¹ Schimmel and Co. Semi-Annual Report, Oct.-Nov., 1906, p. 35.

built of staves 2 inches thick and 2 inches wide, forming with each other a tight joint. Each stave should have a groove one-fourth of an inch by one-fourth of an inch lengthwise on the inside face, and this groove should continue across the end of the stave at the bottom end of the drum. A lining of sheet brass perforated with holes one-sixteenth of an inch in diameter and about an inch apart should be placed inside the drum. The press bag of 10-ounce canvas should be made slightly greater in diameter than the drum and about 6 inches longer than the drum, in order to allow for the folding of the canvas over the top of the cake.

It was found expedient to release the pressure several times in the treatment of a cake, since this apparently facilitates the extraction of the oil. In commercial operations where several presses would be employed this could be done readily by passing the drum from one screw to the next, inasmuch as these screws would probably all be mounted in one frame having a common base.

The still can be purchased from dealers in pharmaceutical and chemical supplies. Heat can be supplied by gas, gasoline, kerosene, or wood stoves. Separatory funnels, glass or tin funnels, filter paper, and any other minor apparatus can be obtained from the dealers mentioned. Burnt lime can also be readily obtained from local dealers. The entire outfit occupies but little floor space and is comparatively inexpensive.

COST OF PRODUCTION.

After the plant is equipped, the cost of producing the oil will depend entirely upon the price paid for the waste fruit and the cost of labor. In the experimental work here recorded the cost was about 15 cents for extracting the oil from a standard field box of oranges of approximately 100 pounds, and it is believed that on a commercial scale the cost will be no greater for fruit delivered at the factory door. By using several presses, as previously mentioned, it is believed that even this cost can be reduced materially.

YIELD OF OIL.

In some preliminary experiments the yield of oil was found to vary greatly according to the variety, stage of growth, climatic conditions, and quality of the fruit. From data secured by laboratory tests on several varieties from a great number of localities the yield was found to range from 2.5 to 9 ounces of oil per 100 pounds of fruit. Satisfactory yields of oil have also been obtained by this process from frosted fruit and from fruit in the earlier stages of stem-end rot or showing only a small decayed spot. The peeling machine, however, will not handle frosted fruits which have become soft or fruits which show large areas of decay.

In commercial experiments with cull fruit obtained at the packing houses at Orlando, Fla., the average yield of oil per 100 pounds of fruit was about 5 ounces. It may safely be assumed that from 4 to 5 ounces of oil can be extracted from every standard field box containing approximately 100 pounds of ordinary cull oranges. At the average price paid for orange oil for the past 10 years the gross returns would be from 47 to 59 cents per field box. The gross return, as determined from actual sales in the markets of New York City, of the oil produced in the experimental work was 54 cents per field box.

SUMMARY.

The extraction of sweet-orange oil is a commercial possibility in the United States. As a source of raw material for extraction the culls, drops, and inferior grades of fruit may be used. A good marketable quality of oil may be produced by the process of vacuum distillation herein described.

Pressed oil extracted by the method described is of excellent quality and a larger yield of oil is secured than by the vacuum process. The process is very simple and the cost of equipment extremely small.

The utilization of inferior or low-grade fruit for the extraction of oil will give a wider market for the better grades of fruit and also tend to greater care in the selection of these grades.

The yield of pressed oil from 100 pounds of ordinary cull fruit is estimated to be from 4 to 5 ounces, and the gross returns from this quantity of oil, based on the average price for the past 10 years, would be from 47 to 59 cents per standard field box.

The cost of extracting the oil from 100 pounds of cull fruit is estimated to be about 15 cents, and the net returns would be from 32 to 44 cents per standard field box, assuming that the fruit is delivered at the factory door.

A DETAILED DESCRIPTION OF A NEW MACHINE FOR PEEL- ING CITRUS FRUITS.

By S. C. HOOD,

Scientific Assistant, Office of Drug-Plant and Poisonous-Plant Investigations.

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INTRODUCTION.

In the United States the production of citrus fruits, especially oranges, grapefruit, and lemons, has reached a stage where there is a demand for more careful grading of the fruit, and consequently the lower grades are gradually being diverted from the fruit trade into the manufacture of various by-products. The first step in the manufacture of these products, whether oils or other materials from the outer peel or food products from the pulp or juice, consists in removing the peel from the fruit. Owing to the tender nature of the fruit and the great variations in its shape and size, it has not been easy to accomplish this with any of the machines now on the market. It was necessary therefore to devise special machinery and apparatus which would work up the fruit at low cost and with a minimum demand on the labor supply of the citrus districts during the busy harvest season. The machine which has thus been devised not only peels the fruit with great rapidity, but also makes it unnecessary to sort the fruit prior to putting it through the machine.

The machine has been thoroughly tested at Orlando, Fla., and it has been found that by its use one man can in one hour remove the peel from 2 tons of oranges or from $3\frac{1}{2}$ tons of grapefruit. The peel comes from the machine in a finely divided condition suitable for the extraction of the oil, and the peeled fruit is delivered in a condition suitable for use in the manufacture of various food products.

This peeling machine has been constructed by the United States Department of Agriculture, has been patented under United States Letters Patent No. 1186317 and is dedicated to the public.

DESCRIPTION OF THE MACHINE.

The machine consists of four essential parts, as follows:

(1) A rapidly revolving drum which removes the peel by a grating action on the fruit.

(2) A spiral feed screw which carries the fruit along the drum, at the same time rotating it in a forward direction so that the peel is removed in the form of spirals.

(3) A feed table of special construction which serves as a support for the fruit while passing through the machine.

(4) An adjustment mechanism to vary the relation of the drum, feed screw, and table in accordance with the character of the fruit to be handled and the degree of its ripeness.

The details of the machine as they appear in both perspective and cross section are shown in figures 6 to 10. Figure 6 is a perspective view of the machine; figure 7, a side view of the machine with the cover removed; figure 8, a top view of the feed table; figure 9, a cross section through the machine; and figure 10, a cross section of the conveyer. The lettering of the various parts of the machine is the same in all of the figures.

The drum (figs. 6, 7, and 9, A).—The drum is 11 feet in length and is made in two parts, each 5 feet 6 inches long, since it is found that if it is built in one piece there is a tendency to sag in the middle, thus causing great vibration when run at the necessary speed. Each part is built of narrow staves 2 inches wide and $1\frac{1}{2}$ inches thick, bolted to cast-iron pulleys 10 inches in diameter and 3 inches face. It was found advisable to cast the pulleys with the spokes set at one side of the rim and with the hub projecting about 2 inches beyond the rim on that side, since this permits easy access to the stave bolts. Each part of the drum requires three pulleys. The end pulleys are set on the shaft, with the hubs inside, and the middle pulley is equidistant from the ends. The shaft is about $1\frac{3}{8}$ inches in diameter, and each pulley is fastened to it with a half-inch set screw.

The staves are secured to the pulleys by a quarter-inch bolt through the middle of the stave at each pulley, and the bolt heads are counter-sunk in the staves to at least a quarter of an inch below the surface. All the staves except three are secured by bolts through holes drilled in the rim of the pulleys, the nuts being secured on the under side of the rim. In the last three staves placed in position, the holes in the middle pulley are threaded the proper size and the cap screws turned in from the outside. The two parts of the drum are set on the shaft 6 inches apart, to permit a middle bearing to be placed in position on the frame. After the staves have been secured in place the drum is turned true, either by placing it on a lathe or by setting it in its frame and turning it by power.

The grating surface of the drum is made of No. 24 galvanized iron, cut into strips 4 inches wide and punched to form the special teeth required. These teeth are formed by a triangular punch with two sides straight and the third beveled to form the point. The punch should be adjusted so that when used on a lead block a triangular tooth will be cut, having one point exposed. The teeth are from three-sixteenths to one-fourth of an inch long, with the point raised from three thirty-seconds to one-eighth of an inch. They are about

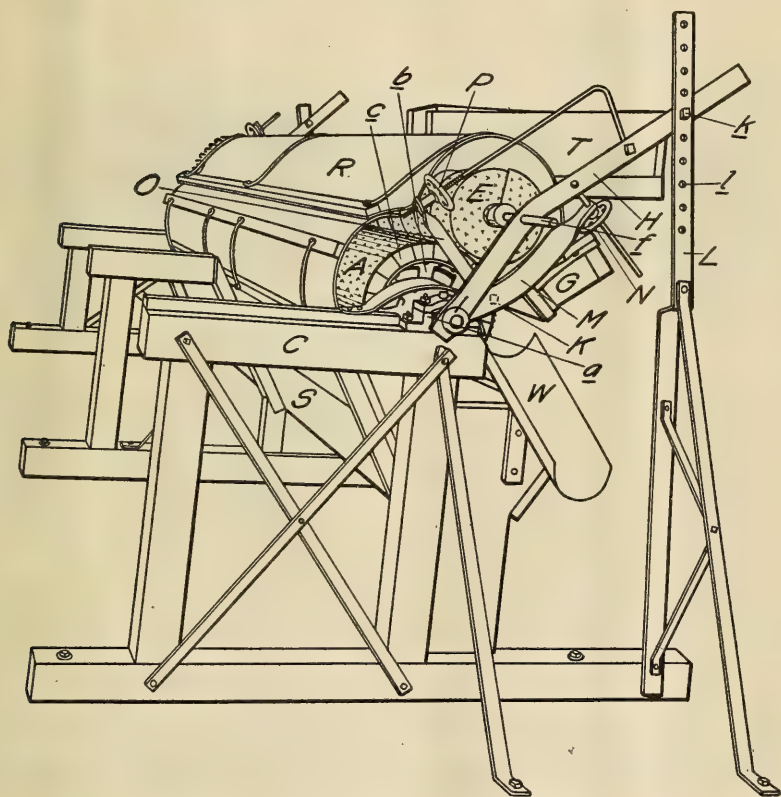


FIG. 6.—Perspective view of the peeling machine.

three-fourths of an inch apart each way and so placed that when the strips are in position on the drum the teeth will project in the direction in which the drum rotates. It is essential that the point and edges of the punch be kept sharp, in order to make a clean-cut tooth having a sharp point. It is desirable to mark off the strips on the sheet of galvanized iron and punch the teeth before cutting the strip, leaving a margin of at least one-half an inch on each edge. This prevents the strips from being warped out of shape in the punching process.

The strips are wound spirally on the drum until it is entirely covered and are then nailed down smooth with No. 3 nails placed about an inch apart. It is essential that no sharp corners or edges of the metal be left projecting, since these will cut the fruit and cause trouble.

The details of the frame construction are shown in figures 6 and 7. The frame is made of pieces 4 by 4 inches mortised together and

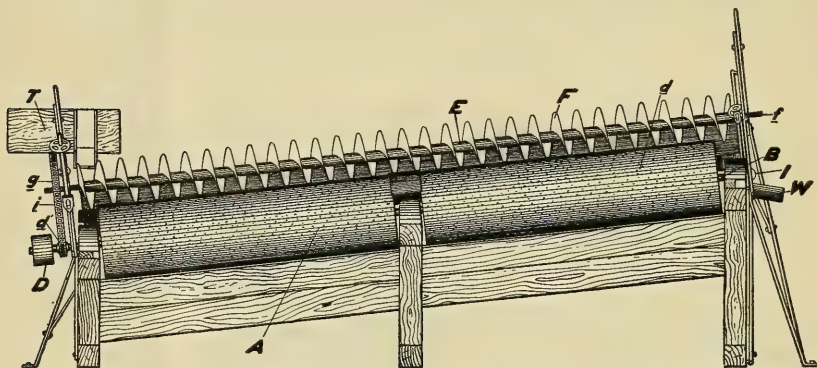


FIG. 7.—Side view of the peeling machine, with the cover removed.

properly braced with iron. At the lower end of the machine the frame is 20 inches high and at the upper end 32 inches high, so that one end of the drum is 12 inches higher than the other. The frame is fastened to the floor by lag screws, the ends being further secured by iron braces in order to receive the end thrust which is caused by the drum being higher at one end.

The feed screw (figs. 6, 7, and 9, E).—The feed screw is the same length as the drum. It is built with 2-inch galvanized-iron pipe as

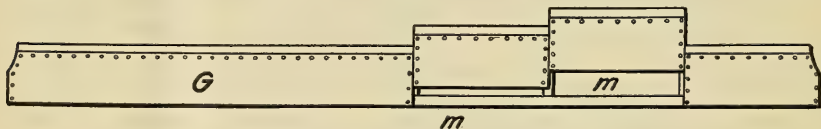


FIG. 8.—Top view of the feed table.

a shaft, on which is soldered a spiral made of 22-gauge galvanized sheet iron. The flights of the spiral are $3\frac{1}{2}$ inches high and 4 inches apart, each flight being made separately. These are then united and soldered to form a continuous spiral and are set on the shaft so that they project forward about 15° . The faces of the flights are punched thickly with the 3-cornered punch, forming points about one-eighth of an inch high on the forward face. This screw is supported by pieces of a $\frac{3}{4}$ -inch shaft set in sleeve collars held inside the pipe by screws. The shaft need not extend more than 2 feet into the pipe at each end.

The feed table (figs. 6, 8, and 9, *G*).—The feed table consists of a wood or iron frame $9\frac{1}{2}$ inches wide, running the entire length of the machine under the feed screw. It should be the length of the machine from outside to outside of the end frames. The top of the frame is covered with a 10-inch board, which is cut into sections as shown in figure 8. These sections are held in place by some sort of fastening on the outside edge, so that they can be drawn out at will. The upper surfaces of these slides are covered with galvanized iron,

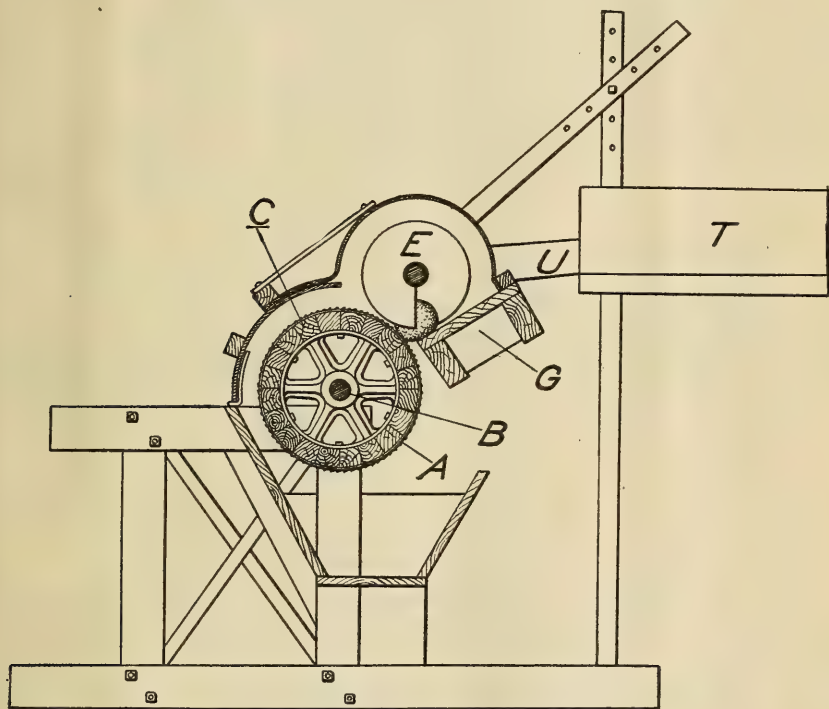


FIG. 9.—Cross section through the machine.

toothed on the inside half in the same manner as the flights of the feed screw but with the teeth a little smaller.

The adjustment mechanism (fig. 6).—The feed screw *E* is supported at each end by an iron bar *H*, attached at the lower end to a babbitted collar *a* on the drum shaft and held at the other end by a vertical standard *L*, in which are several holes *l* for receiving the bolt *k*. The hole in the iron bar *H*, through which the feed-screw shaft *f* extends, should be at such a distance that when the feed screw is in place there will be about one-half inch clearance between the edge of the screw flights and the drum. In case the machine is to be used a great deal, the bearing for the shaft of the feed screw at *f* in the

arm *H* should be reinforced by a babbitted bushing to prevent wear. The short arm *M* is attached at the lower end to the same collar as *H*, and the other end rests on the wheel nut *N*, running on the rod which is secured at the upper end of the arm *H*. By means of this wheel nut the outer end of the arm *M* can be raised and lowered.

The feed table is supported by an iron arm attached underneath and forming a brace to hold the parts of the frame in position. This arm is carried up to the level of the top of the table and bent at right angles to extend in the same plane as the top of the table. At *K* this arm is secured by a bolt to the arm *M* and is then bent upward at right angles, forming the lever *O*. At the top this lever receives the iron rod and rests against the wheel nut *P*. By means of this wheel nut the incline of the table is changed, moving on the bolt *K* as a pivot. It is essential that the center of the bolt *K* should be

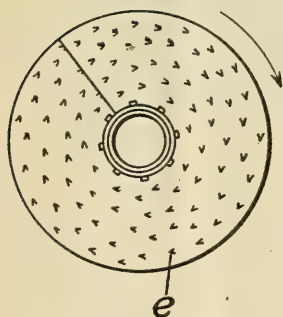


FIG. 10.—Cross section of the conveyer.

in the same plane as the surface of the drum and so arranged that the inside edge of the slides forming the top of the table should be about three-eighths of an inch from the drum.

The shaft of the drum should be furnished with a pulley of 8-inch face, of the proper diameter to drive the drum at 600 revolutions per minute. The feed screw is furnished with a large sprocket wheel and driven by a small sprocket on the drum shaft, of the proper size to turn the feed screw at 150 revolutions per minute.

The peel receptacle.—Underneath the drum is a trough made of tin or galvanized iron to receive the finely divided peel. This trough extends nearly to the floor and toward the front of the machine to a vertical line from the outer edge of the feed table. The back of the trough extends upward to the top of the frame and to it are attached removable covers which entirely inclose the drum and feed screw. These can easily be removed for cleaning and for removing the peel which adheres to them.

OPERATING THE MACHINE.

The fruit to be peeled is placed in a large box (figs. 6, 7, and 9, *T*), the bottom of which is a few inches higher than the top of the drum at the lower end. From this box a narrow spout (fig. 9, *U*) extends to the edge of the feed table. The fruit rolls into this spout and is fed by hand, one at a time, between the two lower flights of the feed screw (see fig. 9), one being delivered at each revolution of the feed screw. The fruit is carried along by this screw in contact with the drum, which removes the peel by grating. As soon as the fruit

comes in contact with the rapidly revolving drum it tends to spin rapidly in the opposite direction, but this is sufficiently retarded by the toothed surface of the table, which supports it, so that it is acted upon by the teeth of the drum. The toothed flights of the feed screw tend to roll the fruit forward on the table, so that the peel is removed in a series of spirals. The peeled fruit is delivered from the spout *W* (figs. 6 and 7).

In adjusting the machine for work the weight which the fruit presents to the drum can be changed by raising or lowering the arm *H* on the standard *L* (fig. 6). By means of the wheel nut *P*, the table can be inclined so as to increase or decrease the angle made with the drum. The smaller this angle is the more tendency there is for the fruit to be pinched against the drum and the more severe the grating action. The wheel nut *N* raises or lowers the arm *M*, so that the table may be kept at the proper distance from the feed screw.

CHANGES REQUIRED FOR THE VARIOUS CITRUS FRUITS.

The dimensions as given are those suitable for oranges or lemons. If it is wished to use this machine for peeling grapefruit a feed screw having flights of the proper size can be constructed and installed in the same manner as has been described. In the case of limes, the screw can be made smaller and shorter.

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UNITED STATES DEPARTMENT OF AGRICULTURE



BULLETIN No. 400

Contribution from the Bureau of Plant Industry
WM. A. TAYLOR, Chief.



Washington, D. C.

PROFESSIONAL PAPER.

October 26, 1916

EXPERIMENTS WITH MARQUIS WHEAT.

By CARLETON R. BALL, *Agronomist in Charge*, and J. ALLEN CLARK, *Scientific Assistant, Western Wheat Investigations, Office of Cereal Investigations.*

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INTRODUCTION.

Marquis wheat has attracted much attention in the United States during the past three or four years. Large quantities of seed have been imported from Canada and sold to farmers in this country. In a period of only three years the production has increased until it has become of commercial importance.

The United States Department of Agriculture has had Marquis wheat under experiment at a number of experiment farms for periods of two or three years. These experiments have been conducted under varying conditions of climate and soil. The results obtained in these tests are shown in this bulletin. In addition, there are given some results obtained independently by State agricultural experiment stations.

The experiments at Ames, Iowa; Brookings, Highmore, Eureka, and Newell, S. Dak.; Dickinson and Williston, N. Dak.; Moccasin, Mont.; Nephi, Utah; Aberdeen, Idaho; and Moro and Burns, Oreg., are conducted in cooperation with the agricultural experiment stations of those States, respectively. The experiments at Akron, Colo., are conducted in cooperation with the Office of Dry-Land Agriculture

NOTE.—This bulletin is intended for agronomists, both experimenters and extension workers, and for technical workers in other lines who are concerned with wheat and its products.

Investigations, and those at Newell, S. Dak., in cooperation with the Office of Western Irrigation Agriculture, both of the Bureau of Plant Industry. The results at Archer, Wyo., were obtained in cooperation with the State board of farm commissioners.

The results at St. Paul and Crookston, Minn.; Langdon and Edgeley, N. Dak.; Lincoln and North Platte, Nebr.; and Davis, Cal., were obtained independently by the agricultural experiment stations of those States. The writers desire to acknowledge their indebtedness to the directors and other officers of these stations and substations for their courtesy in permitting the use of these results. Full credit for these data is given in the text in each case.

The data from Huntley, Mont., and the Truckee-Carson Reclamation Project in Nevada were furnished by the Office of Western Irrigation Agriculture of the Bureau of Plant Industry.

HISTORY OF MARQUIS WHEAT.

It is fortunate that in the case of Marquis wheat its origin is fairly well known and the main facts of its subsequent history can be traced.

The Marquis variety is a hybrid wheat bred by the cerealists of the Dominion Department of Agriculture, at Ottawa, Canada. The present Dominion cerealist has given an account of its origin in the following words:¹

ORIGIN.

A few details in regard to the origin and characteristics of Marquis wheat were given in the report of the Experimental Farms for the year 1906. It seems necessary, now, to treat this subject at somewhat greater length, in view of the exceptional interest which has lately been aroused in this wheat.

Among the crosses made by the director of experimental farms and his assistants during the first few years after the farms were established, several were effected between Red Fife and various early-maturing wheats from Europe and Asia. All the details in regard to the origin of Marquis are not available, but it is one of the descendants of a cross between an early-ripening Indian wheat, Hard Red Calcutta (as female) and Red Fife (as male). The cross (as appears from unpublished notes) was made by Dr. A. P. Saunders, probably at the experimental farm at Agassiz, in the year 1892. The crossbred seeds, or their progeny, were transferred to Ottawa and when the writer of this report was appointed in 1903 to take charge of the work of cereal breeding, he made a series of selections from the progeny of all the crossbred wheats which had been produced at Ottawa up to that time. Some of these had been named and others were under numbers. Though they had all been subjected to a certain amount of selection, each of them consisted of a mixture of related types. In some cases all the types present were similar. In other instances striking differences were observed. The grain which had descended from the cross referred to above was found by careful study of individual plants (especially by applying the chewing test to ascertain the gluten strength and probable bread-making value) to be a mixture of similar-looking varieties which differed radically in regard to gluten quality. One of the varieties isolated from this mixture was subsequently named

¹ Saunders, C. E. Marquis wheat. *In* Canada Exp. Farms Rpts. [1911-1912], p. 118-120. 1912.

Marquis. Its high bread-making strength and color of flour were demonstrated in the tests made at Ottawa in the early months of 1907, and all the surplus seed was at once sent to the Indian Head Experimental Farm for propagation.

It will be clearly seen from the above account that the question, "When was Marquis wheat originated?" can never be answered. It came into existence probably at Ottawa between the years 1895 and 1902. It remained, however, mixed with other related sorts until discovered by the writer in 1903. It was first grown in a pure state in 1904, when a few seeds were sown in a sheltered garden on the Central Experimental Farm. Even then, however, its fine qualities were only partly known, and it was not until the cerealists' baking tests of 1907 were completed that he decided to send out this wheat for trial in Saskatchewan. Its success in the prairie country was phenomenal.

EXPERIMENTS IN WESTERN CANADA.

Marquis wheat was first sent to the Prairie Provinces of Canada in the spring of 1907. The report states that it immediately won a phenomenal success. This success was not due to any lack of able competitors.

For nearly two decades previous to 1907 the Red Fife had been the most popular and highest yielding wheat grown in the Prairie Provinces of Canada. It had been grown in a varietal test at the Indian Head Experimental Farm in Saskatchewan continuously since 1888. Within this 18-year period, 98 other varieties were compared with the Red Fife. Only two of these, the White Fife and Red Fern, were grown throughout the entire 18 years. The average acre yield of the Red Fife during this period was 37.6 bushels. It outyielded both other varieties, though the average acre yield of the White Fife was 36.4 bushels.

At the Brandon Experimental Farm in Manitoba, the Red Fife was grown continuously for 17 years, 1890 to 1906, inclusive. During all or varying parts of this period, 85 other varieties and strains were compared with it. Only five others were grown throughout the 17 years. The Red Fife, with a 17-year average acre yield of 33.7 bushels, outyielded all the others except one. This one was the White Fife, with an average acre yield of 34.2 bushels.

These data show the Red Fife and White Fife to be good varieties and that any variety outyielding them must possess real merit.

Marquis wheat was introduced into experiments at Indian Head, Saskatchewan, in 1907; at Brandon, Manitoba, and Lethbridge, Alberta, in 1908; and at Rosthern, Saskatchewan, in 1911. Table I shows the yield of the Marquis and Red Fife varieties at these stations from the year of introduction to 1914 and the average yield of each in the period during which they were grown. These data have been taken from the published annual reports of the Canadian experimental farms.

TABLE I.—*Annual and average yields of Marquis and Red Fife wheat, grown at four of the Canadian experimental farms during varying periods within the years 1907 to 1914, inclusive.*

Station and variety.	Yield per acre (bushels).								
	1907	1908	1909	1910	1911	1912	1913	1914	Average.
Indian Head, Saskatchewan:									
Marquis.....	32.0	46.3	37.5	48.0	50.4	77.4	56.7	54.0	50.3
Red Fife.....	12.0	35.0	24.8	43.0	26.4	64.0	39.3	46.7	36.4
Brandon, Manitoba:									
Marquis.....		49.2	43.3	42.7	46.6	36.6	50.5	36.5	43.6
Red Fife.....		41.5	40.2	40.7	42.6	36.0	45.0	22.6	38.4
Lethbridge, Alberta:									
Marquis.....		29.2	31.0	11.0	-----	28.5	30.0	-----	25.9
Red Fife.....		33.8	29.0	15.0	-----	31.1	24.7	-----	26.7
Rosthern, Saskatchewan:									
Marquis.....					70.0	43.3	54.0	45.3	53.1
Early Red Fife.....					60.0	27.3	36.0	43.1	41.7

A study of Table I shows that the Marquis outyielded the Red Fife at three of these stations by 5 to 14 bushels per acre. At Lethbridge the Red Fife outyields Marquis by four-fifths of a bushel per acre. The Kharkof, a hard red winter wheat, also outyields the Marquis at Lethbridge.

The overyield of the Marquis at Indian Head is 38.2 per cent; at Rosthern, 27.3 per cent; and at Brandon, 13.5 per cent.

INTRODUCTION INTO THE UNITED STATES.

Attention was first attracted to Marquis wheat in the United States through its having won premiums at several expositions. In consequence of this publicity a demand for the seed arose. A considerable quantity of seed was brought into this country for sowing in 1913. Much larger quantities were imported for sowing in 1914. One firm in North Dakota claims to have handled 140,000 bushels in the latter year.

The importations of these two years, with the seed home grown in 1913, were sufficient to sow about half a million acres in 1914. The three States, Minnesota and the Dakotas, produced 6,360,000 bushels in 1914. The total crop of 1914 was probably about 7,000,000 bushels. This gave a large supply of home-grown seed, and very little has been imported since.

Most of the imported seed was sold in Minnesota, North Dakota, and Montana. Smaller quantities were sold in Iowa, Nebraska, South Dakota, and Washington. In this way the Marquis variety became widely distributed in a very short time.

DESCRIPTION OF MARQUIS WHEAT.

In all important characters Marquis wheat closely resembles the wheats of the Fife group, so commonly grown in the northern Great Plains States. It is therefore included in the Fife group. It will be

remembered that the Red Fife was the male parent of the Marquis and that it doubtless was selected for Fife characters.

The Marquis is a beardless spring wheat, with white glabrous glumes and broad and short hard red kernels. In general it differs from the



FIG. 1.—Heads and kernels of three varieties of hard spring wheat, natural size: 1, Marquis; 2, Glyndon; 3, Haynes.

true Fife varieties in its shorter straw, shorter spike, shorter glumes, and shorter, broader kernel. (Figs. 1 and 2.)

The plants are of only medium height, ranging from 28 to 48 inches, according to season. They generally are 2 to 4 inches shorter than

those of the Glyndon and Power wheats. The straw is stiff and stands up well under unfavorable weather conditions. The spikes are short, varying from 2.5 to 4 inches in length. They average one-half to 1 inch shorter than those of other varieties of the Fife group (fig. 1).

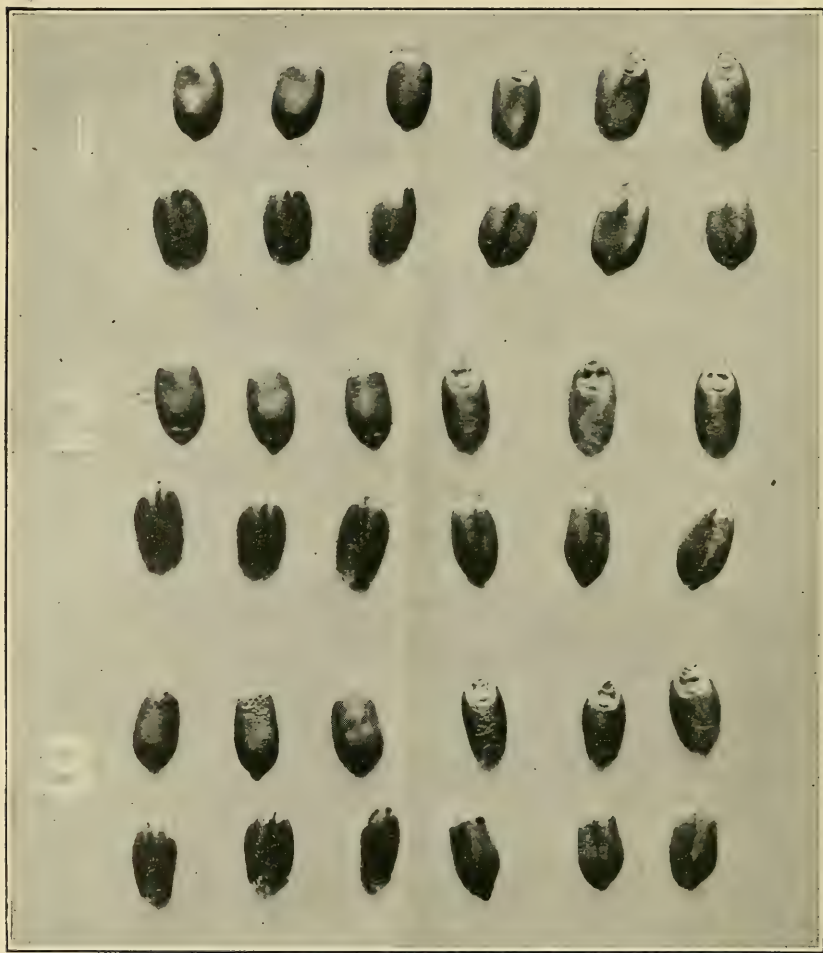


FIG. 2.—Kernels of three varieties of hard spring common wheat, shown in four different positions, twice natural size: 1, Marquis; 2, Glyndon; 3, Haynes.

Two or three short awns usually are found at the tip of the head, as in other beardless wheats.

The glumes of the Marquis variety are short and broad. The variety usually can be recognized, even before the seed is ripe, by this character and by its lower stature. In spite of the short glumes the seed is held firmly and does not shatter.

The kernels of other Fife wheats are short and broad, but those of the Marquis are even more so. They vary from 4.5 to 6 millimeters

in length, averaging 5.2 millimeters, or nearly 1 millimeter shorter than the kernels of Fife and Bluestem wheats (fig. 2). The crease also is broader and deeper.

The Marquis is an early variety, ripening from 98 to 135 days after sowing, varying with the season and locality. The average length of its growing period in the northern Great Plains is about 115 days. This makes it three or four days earlier than most of the other Fife varieties. Because of its earliness it escapes to some extent the drought of dry years, the rust and fall rains of wet seasons, and also the early fall frosts. These are the characters which have made it especially valuable in the Prairie Provinces of Canada.

The growing season lengthens as one passes southward into the United States, and earliness is no longer so great an advantage.

VARIETAL EXPERIMENTS.

As soon as the Marquis wheat began to attract attention in 1912 the United States Department of Agriculture began an extensive series of varietal experiments with it.

SOURCE OF THE SEED.

A small supply of seed (C. I. No. 3276) was obtained from Dr. C. E. Saunders, of Ottawa, in January, 1912. This was grown in the nurseries at several stations, but became the basis of the varietal experiments in plats only at Aberdeen, Idaho, and Newell, S. Dak. A larger supply (C. I. No. 3641) was obtained from the Lethbridge Experimental Farm in Alberta, in the early spring of 1913. This lot has been used in the varietal experiments of the Department of Agriculture, except in Idaho and Oregon and at Newell, S. Dak. In the spring of 1913 the Eastern Oregon Dry-Farming substation at Moro obtained a supply of seed direct from the Indian Head Experimental Farm in Saskatchewan. This lot of seed was given Cereal Investigations No. 4158 and has been used in the varietal experiments at Moro and Burns, Oreg. The sources of the seed used by the State experiment stations conducting independent tests are not known.

GEOGRAPHIC AREA COVERED.

The experiments recorded herein have been conducted in 13 different States. The area stretches from Iowa and Minnesota on the east to California and Oregon on the west. All the intervening States are included except Washington.

In this great expanse of territory the conditions of climate and soil vary greatly. Naturally the adaptation and value of Marquis wheat vary with local conditions. The eastern portion of this territory is distinctly humid in climate, and the soil consists of glacial drift and alluvium. Progressing westward into the northern section of the Great Plains area marked changes occur, especially in the climatic

factors. In general the precipitation decreases, the elevation increases, and the growing season becomes shorter. The soils become heavy clay loams, varying to heavy clays or gumbo on the one hand and to sandy loams and sands on the other.

West of the Rocky Mountains a new set of conditions present themselves. The precipitation usually is low, and sometimes very low. The elevation in the great interior basins is high, except in the Columbia Basin, where it seldom exceeds 2,000 feet. The soils are light in texture. In the California valleys the elevation is low.

In the Rocky Mountain region and westward irrigation is practiced where water and topography permit. Marquis wheat has been tested under irrigation as well as by dry-farming methods in the semiarid and arid portions of the territory covered.

For convenience in presenting the results obtained, the territory under discussion may be separated into four divisions, according to the prevailing conditions. These divisions may be called (1) the northern Prairie States, or subhumid section; (2) the northern Great Plains States, or semiarid section; (3) the Basin and Coast, or arid areas, including the Great Basin, the Snake River basin, the Harney Valley, the Columbia basin, and the California valleys; and (4) the irrigated districts of the northern Rocky Mountain region and Great Basin areas.

RESULTS OBTAINED.

The results of varietal experiments reported in this paper have been obtained at 22 different experiment stations. At 15 of these stations, in nine different States, the experiments are conducted by the Office of Cereal Investigations, usually in cooperation with the State agricultural experiment station or some other agency. At eight different stations in four States the results given have been obtained independently by the State agricultural experiment station or other agency. The source of the data is explained in connection with each station.

The experimental conditions have varied somewhat at some of the stations. The results obtained at one station, therefore, are not necessarily directly comparable with those obtained at another station. In most cases, however, they probably are directly comparable.

In all cases the results from different varieties at the same station were nearly always obtained under similar conditions and may be directly compared. Any known exceptions to this fact are stated in the text.

At each station the aim has been to grow the experimental crops under conditions approximating good farm practice for that locality. All crops have been grown by means of only the natural rainfall except those discussed in the fourth division, which were grown under irrigation.

RESULTS IN THE NORTHERN PRAIRIE STATES.

This section covers the northern Prairie States lying west of the Mississippi River. It includes Iowa, Minnesota, and the subhumid eastern parts of Nebraska and the two Dakotas. Only the narrow limits of the Sioux Valley of South Dakota and the Red River Valley of North Dakota can be classed as subhumid in these two States.

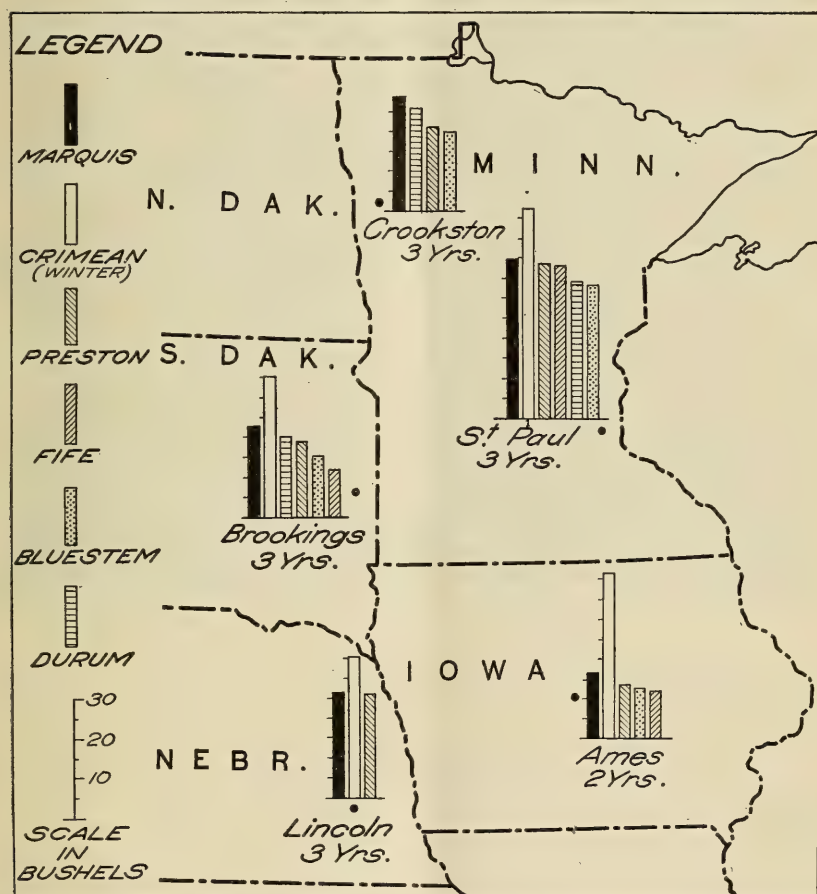


FIG. 3.—Diagram showing the average yields of the Marquis and the leading variety in each of several different groups of wheat at five stations in the northern Prairie States, during either two or three of the years 1913 to 1915, inclusive.

Marquis wheat has been grown to a considerable extent in this subhumid part of the upper Mississippi Valley. About one and one-third millions of bushels were grown in Minnesota alone in 1914. The variety has been tested at several experiment stations located in this section. The positions of five such stations and the results obtained during the last three years are shown in figure 3. The

stations are Ames, Iowa; Lincoln, Nebr.; Brookings, S. Dak.; and St. Paul and Crookston, Minn.

Figure 3 shows by means of graduated columns the average yield of Marquis wheat and of the leading variety in each of several groups of wheat during the 3-year period, 1913 to 1915, except as otherwise noted. The same data will be found in tabulated form in Tables III to VII, inclusive.

The annual rainfall at each of these stations during 1913, 1914, and 1915, so far as available, and the average for the 3-year period, together with the elevation, are shown in Table II. The average annual rainfall at Ames, Iowa, not shown in the table, is about 40 inches. From this there is a decrease at the other stations. Crookston, Minn., has the lowest average, a little less than 20 inches. Brookings, S. Dak., has the highest elevation.

TABLE II.—*Altitude, annual precipitation, and seasonal precipitation at five experiment stations in the northern Prairie States, or subhumid section, during 1913, 1914, and 1915, except as otherwise noted.*

Station.	Altitude.	Precipitation (inches).							
		Annual.				Seasonal. ¹			
		1913	1914	1915	Average.	1913	1914	1915	Average.
	<i>Feet.</i>								
Ames, Iowa.....	922		(²)	33.66			(²)	12.85	
Lincoln, Nebr.....	1,189	26.23	40.02	36.81	34.35	12.30	20.70	11.81	14.94
Brookings, S. Dak.....	1,636	16.58	24.15	20.42	20.38	10.69	14.09	10.47	11.75
St. Paul, Minn.....	837	24.05	24.62	30.79	26.49	13.73	12.65	14.74	13.71
Crookston, Minn.....	863	16.20	23.03	20.11	19.78	8.62	14.38	14.98	12.66

¹ The records of seasonal precipitation include the months of April to June, inclusive, at Ames and Lincoln and the months of May to July, inclusive, at the other stations.

² No records available.

The annual rainfall is usually sufficient for normal crop production. Nearly half of the annual precipitation falls during the four months of May, June, July, and August. The growing season is fairly long, varying from about 130 days to as many as 150 days.

RESULTS AT AMES, IOWA.

As shown in Table III, Marquis wheat has been grown only two years at this station. The data show that the hard red winter wheats of the Crimean group far outyield any spring wheats. The Marquis is compared, however, with three other spring wheats. These varieties represent the three different groups of hard spring common wheat which are extensively grown in the hard spring-wheat States. In these two years the Marquis outyielded them all by 3 to 4 bushels to the acre. Representative heads and kernels of the

Preston (spring common), Kubanka (spring durum), and Crimean (winter) groups are shown in figures 4 and 5.



FIG. 4.—Heads and kernels of three varieties of hard wheat, one-half natural size: 1, Preston (spring common); 2, Kubanka (spring durum); 3, Kharkof (winter).

TABLE III.—*Annual and average yields of the Marquis and six other varieties of wheat grown at the Iowa Agricultural Experiment Station, Ames, Iowa, during 1914 and 1915.*

[Data obtained in cooperation with the Iowa Agricultural Experiment Station.]

Group and variety.	Yield per acre (bushels).		
	1914	1915	Average.
Fife:			
Marquis.....	12.0	21.0	16.5
Glyndon (Minn. No. 163).....	12.0	12.3	12.2
Crimean (winter):			
Turkey (Iowa No. 404).....	41.7	40.7	41.2
Turkey.....	34.1	39.2	36.7
Kharkof.....	33.3	38.8	36.1
Preston:			
Early Java.....	11.9	15.3	13.6
Bluestem:			
Haynes (Minn. No. 169).....	12.7	13.0	12.9

RESULTS AT LINCOLN, NEBR.

The experiments reported in Table IV were conducted independently by the Nebraska Agricultural Experiment Station, and the results are made available here through the courtesy of its director and other officers. The yields obtained from the Marquis, Turkey,

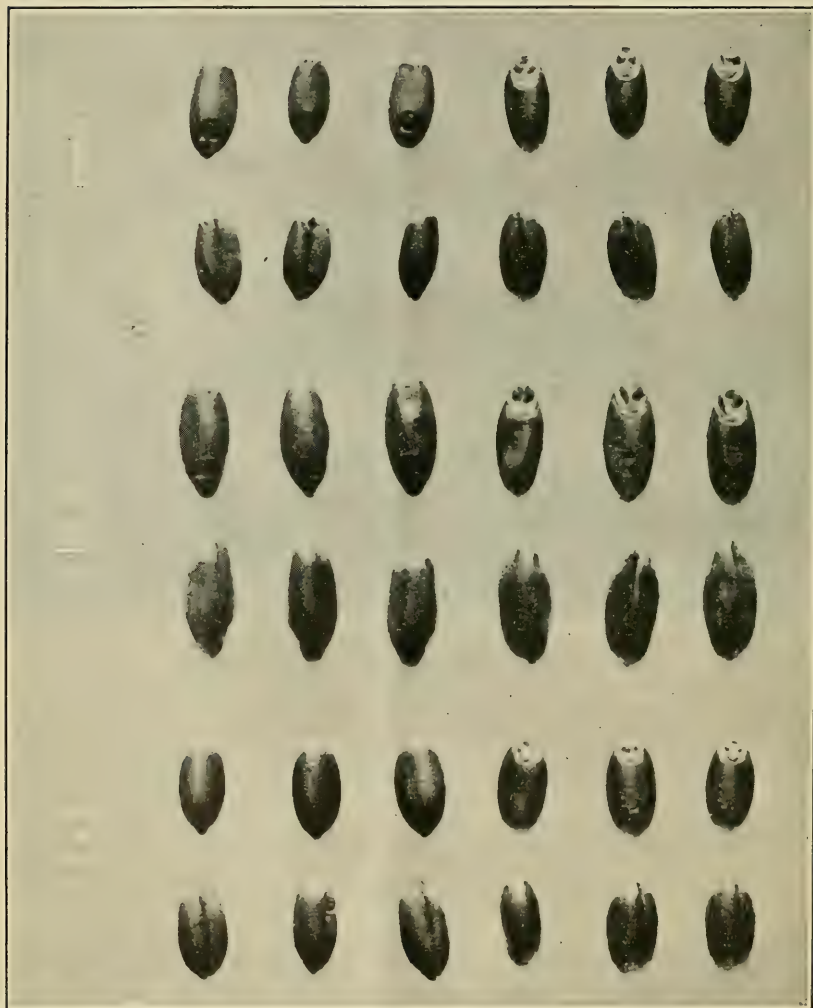


FIG. 5.—Kernels of three varieties of hard wheat, shown in four different positions, twice natural size: 1, Preston (spring common); 2, Kubanka (spring durum); 3, Kharkof (winter).

and Preston varieties during three years are given. The 3-year average yield of the Marquis is about 8 bushels less than that of the Turkey, although it outyielded the Turkey in 1914. Its average yield exceeds that of the Preston, a bearded spring wheat, by only 1.4 bushels per acre.

Concerning the Marquis wheat, Prof. T. A. Kiesselbach, agronomist at the Nebraska Agricultural Experiment Station, says:

It has been our observation that the quality of the Marquis grain is usually somewhat inferior to the grain of the other varieties. The seed is usually more shrunken.

TABLE IV.—*Annual and average yields of the Marquis and two other varieties of wheat grown at the Nebraska Agricultural Experiment Station, Lincoln, Nebr., 1913 to 1915, inclusive.*

[Data presented by courtesy of the Nebraska Agricultural Experiment Station.]

Group and variety.	Yield per acre (bushels).			
	1913	1914	1915	Average.
Fife:				
Marquis.....	32.6	33.7	16.0	27.4
Crimean (winter):				
Turkey.....	48.3	28.8	28.7	35.3
Preston:				
Preston ¹	31.6	29.3	16.8	26.0

¹ Average yields of two varieties grown as "Scotch Fife" and "Swedish," both of which proved to be the Preston variety.

RESULTS AT BROOKINGS, S. DAK.

Cooperative varietal experiments with Marquis wheat have been conducted during three years at the South Dakota Agricultural Experiment Station at Brookings. The annual and average yields of the Marquis and eight other varieties, representing five different groups of wheat, are given in Table V.

TABLE V.—*Annual and average yields of the Marquis and eight other varieties of wheat grown at the Brookings (S. Dak.) station, 1913 to 1915, inclusive.*

[Data obtained in cooperation with the South Dakota Agricultural Experiment Station.]

Group and variety.	C. I. No.	Yield per acre (bushels).			
		1913	1914	1915	Average.
Fife:					
Marquis.....	3641	29.3	15.8	26.7	23.9
Glyndon.....	2873	19.2	9.2	7.5	12.0
Crimean (winter):					
Turkey.....	3055	34.2	30.8	43.3	36.1
Kubanka (durum):					
Kubanka.....	1440	28.3	15.0	17.0	20.1
Arnautka.....	4072	25.8	11.2	22.5	19.8
Preston:					
Preston.....	3081	27.6	12.7	18.3	19.5
Preston.....	3328	22.3	5.8	21.6	16.6
Bluestem:					
Dakota.....	3083	26.7	8.3	12.1	15.7
Marvel.....	3082	22.7	5.7	11.6	13.3

It will be noted that the Turkey, a hard red winter wheat, outyields all spring wheats by more than 12 bushels to the acre. Among the spring wheats, however, the Marquis outyields all other varieties, including five common wheats and two durum wheats. The durum varieties outyield all spring common wheats except the Marquis. The

average yield of the Marquis exceeds that of the Kubanka by about 15 per cent, and that of the best Preston by more than 18 per cent. It much excels the Bluestem varieties and nearly doubles the yield of the Glyndon Fife.

RESULTS AT ST. PAUL, MINN.

The experiments recorded in Table VI were conducted independently by the Minnesota Agricultural Experiment Station, and the results are presented here through the courtesy of the director and other officers.

Table VI shows that in the two years when data on winter wheat are available, the Turkey variety outyielded all the leading varieties of spring wheat. In the 3-year average yield, the Marquis slightly out-yields all other varieties of spring wheat. The quantities by which it exceeds the Preston and Glyndon, however, are too small to be significant, amounting to 2.5 and 4 per cent, respectively. The advantage of the Marquis over the Haynes and Kubanka is about 15 per cent in each case. The 2-year average yield of the Turkey is about 35 per cent higher than that of the Marquis.

In correspondence, Profs. Andrew Boss and A. C. Army state that these varieties were grown on small duplicated plats, 3 by 132 feet, with cultivated 2-foot alleys on either side. The yields, therefore, are higher than those obtained on larger plats and in fields, but are comparable one with another.

TABLE VI.—*Annual and average yields of the Marquis and five other varieties of wheat grown at the Minnesota Agricultural Experiment Station, University Farm, St. Paul, Minn., 1913 to 1915, inclusive.*

[Data presented by courtesy of the Minnesota Agricultural Experiment Station.]

Group and variety.	Minn. No.	Yield per acre (bushels).				
		1913	1914	1915	Average.	
					Two-years.	Three-years.
Fife:						
Marquis.....	1239	41.9	27.7	50.0	38.9	39.9
Glyndon.....	285	38.6	27.0	49.2	38.1	38.3
Crimean (winter):						
Turkey.....	845		47.8	57.0	52.4	
Preston:						
Preston.....	924	43.5	26.5	46.7	36.6	38.9
Kubanka (durum):						
Kubanka.....	990	25.7	30.3	46.7	38.5	34.2
Bluestem:						
Haynes.....	169	33.8	26.7	39.9	33.3	33.5

RESULTS AT CROOKSTON, MINN.

The experiments at Crookston, Minn., have been conducted by the Minnesota Agricultural Experiment Station. The results are available through the courtesy of the director of the station and his asso-

ciates. The Marquis variety has been grown during three years, 1913 to 1915, inclusive, and the annual and average yields of this and other varieties are shown in Table VII. The average yield of each variety is given graphically in figure 3.

The data show that the Marquis outyields any of the other three varieties, representing three separate groups of wheat. It excels the Kubanka by only 5 per cent, but exceeds the Preston and Bluestem by 25 and 30 per cent, respectively. Two plats of Marquis wheat were grown each year, the original seed having been received from separate sources. The yields given are an average of the yields of the two plats. The Glyndon, a Fife variety, was grown in 1913 and yielded 17.4 bushels to the acre, while the two Marquis plats yielded 20.5 and 22.3 bushels, respectively. Winter wheat has not been grown successfully in this part of Minnesota.

TABLE VII.—*Annual and average yields of the Marquis and three other varieties of wheat grown at the Northwest Experiment Station, Crookston, Minn., 1913 to 1915, inclusive.*

[Data presented by courtesy of the Minnesota Agricultural Experiment Station.]

Group and variety.	Yield per acre (bushels).				Group and variety.	Yield per acre (bushels).			
	1913	1914	1915	Average.		1913	1914	1915	Average.
Fife:					Preston:				
Marquis ¹	21.4	23.9	40.0	28.4	Preston.....	18.2	17.7	28.1	21.3
Kubanka (durum):					Bluestem:				
Kubanka.....	27.8	14.6	38.0	26.8	Haynes (Minn. No. 169).....	17.4	19.2	23.3	20.0

¹ Average of the yields of two lots.

CONCLUSIONS.

Two facts are shown clearly by figure 3 and Tables III to VII, inclusive, on which figure 3 is based. These facts are (1) that where hard red winter wheats of the Crimean group can be grown in this section they outyield any spring wheat, and (2) that Marquis wheat outyields other varieties of spring wheat at all these stations. These results are based on 3-year tests at all stations except Iowa, where they cover only two years.

The gain in yield of the Marquis over other spring wheat varieties belonging to the Fife, Bluestem, and Preston groups is small. At St. Paul, Minn., and Lincoln, Nebr., the difference is only about 1½ bushels. In central Iowa and eastern South Dakota it is 3 to 4 bushels. At Crookston, Minn., however, the difference is about 7 bushels. The gain in yield of the Marquis over durum wheats at the three northern stations in this section varies from 1.5 to more than 5 bushels.

RESULTS IN THE NORTHERN GREAT PLAINS AREA.

The northern half of the Great Plains area includes most of Nebraska and the Dakotas, northeastern Colorado, eastern Wyoming, and the eastern half of Montana.

It was to the northern States of this division that Marquis wheat was first introduced. It is in the Dakotas and Montana that it has

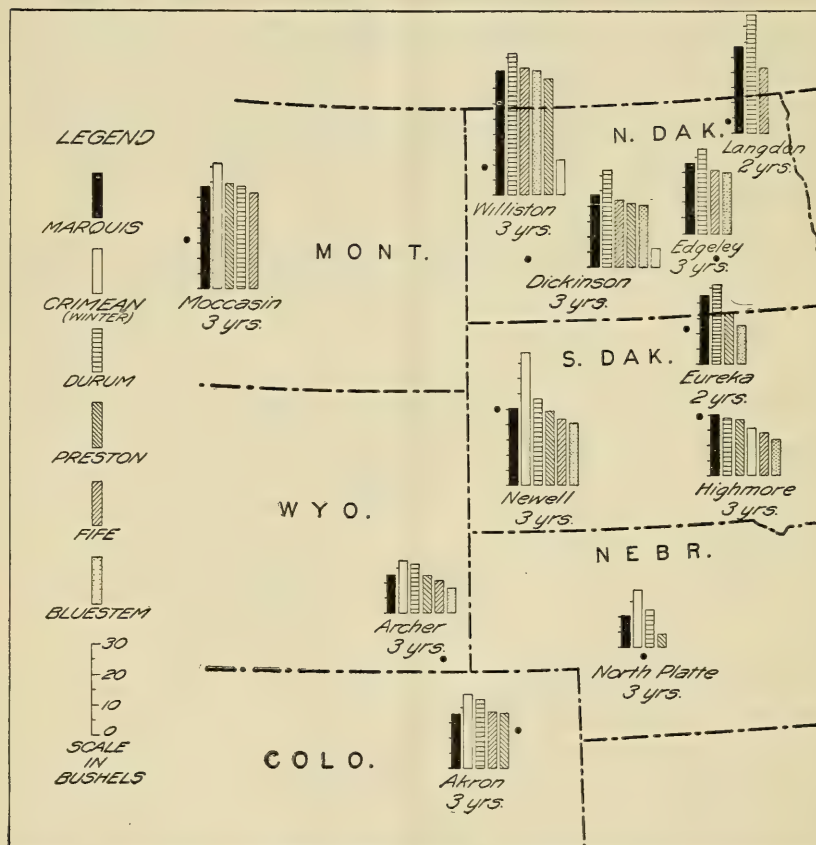


FIG. 6.—Diagram showing the average yields of the Marquis and the leading variety in each of several different groups of wheat at 11 stations in the northern Great Plains area during either two or three of the years 1913 to 1915, inclusive.

become most extensively grown. In 1914 North Dakota alone produced over four millions of bushels and South Dakota nearly a million bushels. No data for Montana were gathered. If statistics for the production in 1915 were available, the increase in these three States would be found to be enormous.

Varietal experiments with the Marquis and other wheat varieties have been conducted under dry-land conditions at nine experiment stations in this section during the three years, 1913 to 1915, inclusive,

and at two others during the last two years of this period. The stations are as follows: North Platte, Nebr.; Akron, Colo.; Archer, Wyo.; Newell, Highmore, and Eureka, S. Dak.; Edgeley, Langdon, Williston, and Dickinson, N. Dak.; and Moccasin, Mont. The location of these 11 stations and the results of the varietal experiments are shown graphically in figure 6. By means of graduated columns the average yield of Marquis wheat is shown with that of the leading variety in each of several groups of wheat grown commercially in these States. The same data will be found in Tables IX to XIX, inclusive.

The climate of this section is generally classed as semiarid. Table VIII shows the altitude of each station and the records of annual and seasonal rainfall during the three years, 1913 to 1915, inclusive, when the varietal experiments were in progress. In the three years under discussion the average annual rainfall has varied between 15 and 20 inches at all these stations except North Platte, Nebr. The higher average at that station is due entirely to the enormous precipitation of the year 1915. In general, the annual rainfall decreases in passing westward across this section. The altitude steadily increases from east to west, varying from 1,000 or 1,500 feet on the eastern border to 6,000 feet in eastern Wyoming and Colorado.

TABLE VIII.—*Altitude and annual and seasonal precipitation at 11 experiment stations in the semiarid northern section of the Great Plains area.*

Station.	Altitude.	Precipitation (inches).							
		Annual.				Seasonal. ¹			
		1913	1914	1915	Average.	1913	1914	1915	Average.
	<i>Feet.</i>								
North Platte, Nebr.....	3,000	18.52	16.10	34.85	23.16	9.02	8.12	19.56	12.23
Akron, Colo.....	4,560	16.05	15.58	25.00	18.88	6.81	10.67	14.17	10.55
Archer, Wyo.....	6,027	16.80	11.60	18.32	15.57	9.26	8.52	12.69	10.16
Newell, S. Dak.....	2,950	12.53	11.70	21.02	15.08	5.68	7.03	15.83	9.51
Highmore, S. Dak.....	1,890	12.46	17.52	23.29	17.76	8.59	11.98	16.40	12.32
Eureka, S. Dak.....	1,884		14.50	24.89	19.70		9.80	12.45	11.12
Edgeley, N. Dak.....	1,468	19.82	17.80	21.96	19.86	9.06	13.06	13.88	12.00
Langdon, N. Dak.....	1,615		17.43	17.55	17.49		7.42	9.15	8.27
Williston, N. Dak.....	1,875	15.27	18.47	14.62	16.12	5.95	12.00	7.23	8.39
Dickinson, N. Dak.....	2,453	11.93	22.74	20.53	18.40	5.43	18.84	14.41	12.89
Moccasin, Mont.....	4,228	14.96	15.67	20.68	17.10	9.32	9.38	11.06	9.92

¹ The record for seasonal precipitation includes the four months of April, May, June, and July at all stations except North Platte, Nebr., and Archer, Wyo. At North Platte the record is for the four months of March, April, May, and June. At Archer the record is for the five months of April, May, June, July, and August.

Crop production is governed largely by the quantity and distribution of the annual precipitation. Reference to Table VIII shows that one-half to two-thirds of the total comes during the growing season of four months. Wind movement is fairly constant and summer temperatures rather high. These factors cause loss of water by evaporation. Hot winds and hail sometimes occur. Wet, warm weather in midsummer sometimes promotes epidemics of rust.

The length of the growing season varies with the altitude and latitude. The frost-free period decreases from about 130 days in the lower portions to about 90 days at the higher elevations. In general, early and drought-resistant varieties have an advantage in escaping hot winds, drought, and frost. A brief popular classification and description of the important groups of hard spring wheat and the leading varieties in each group is already available.¹

RESULTS AT NORTH PLATTE, NEBR.

The experiments reported in Table IX were conducted independently by the Nebraska Agricultural Experiment Station, and the results are made available here through the courtesy of the director and other officers. They have been continued through the 3-year period, 1913 to 1915, inclusive.

Table IX shows that the Turkey wheat, a hard red winter variety, largely outyields all the spring wheats. The advantage of the Turkey over Kubanka No. 1, a durum wheat and the highest yielding spring variety, is 54 per cent. The durum varieties slightly outyield the Marquis, while the durums and the Marquis all outyield the Preston. It is unfortunate that no other variety of the Fife group has been grown at North Platte. The results in hand do not show whether or not the Marquis would outyield other Fife wheats.

TABLE IX.—*Annual and average yields of the Marquis and five other varieties of wheat grown at the North Platte substation, 1913 to 1915, inclusive.*

[Data presented through the courtesy of the Nebraska Agricultural Experiment Station.]

Group and variety.	Yield per acre (bushels).			
	1913	1914	1915	Average.
Fife:				
Marquis.....	6.8	4.3	20.2	10.4
Crimean (winter):				
Turkey ¹	17.3	8.0	31.1	18.8
Kubanka and Kahla (durum):				
Kubanka No. 1.....	7.7	3.9	25.1	12.2
Kubanka ²	7.9	2.3	21.6	10.6
Kahla.....	9.8	2.9	19.2	10.6
Preston:				
Preston ³	3.0	3.0	6.6	4.2

¹ Average yields from nine plats in the rotations of the Office of Dry-Land Agriculture Investigations.

² Average yield of two plats.

³ This variety was grown under the name "Scotch Fife."

RESULTS AT AKRON, COLO.

At Akron, Marquis wheat has been compared with other winter and spring varieties during the 3-year period, 1913 to 1915, inclusive. The annual and average yields are shown in Table X, and the average results appear graphically in figure 6.

¹ Ball, C. R., and Clark, J. A. Varieties of hard spring wheat. U. S. Dept. Agr., Farmers' Bul. 680, 20 p., 7 fig. 1915.

The data show that here also the hard red winter wheats of the Crimean group outyield any spring wheat. The margin of advantage, however, is not wide. Considering only the spring wheats it is seen that the three durum varieties outyield any of the spring common varieties by 3 to 5 bushels per acre. Among the five spring common wheats, the Marquis ranks third, being slightly exceeded by the Ghirka Spring, of the Fife group, and a bearded variety called Red Russian, of the Preston group. Among the entire 11 varieties the Marquis ranks ninth.

TABLE X.—*Annual and average yields of the Marquis and seven other varieties of spring wheat and three varieties of winter wheat grown at the Akron Field Station, Akron, Colo., 1913 to 1915, inclusive.*

[Experiments conducted in cooperation with the Office of Dry-Land Agriculture Investigations.]

Group and variety.	C. I. No.	Yield per acre (bushels).			
		1913	1914	1915	Average.
Fife:					
Marquis.....	3641	7.5	19.7	26.5	17.9
Ghirka Spring.....	1517	14.0	19.3	22.6	18.6
Glyndon.....	2873	8.0	16.6	16.2	13.6
Crimean (Winter):					
Kharkof 6P4.....	4207	18.5	26.1	28.3	24.3
Kharkof.....	1583	16.6	25.9	29.2	23.9
Do.....	1442	16.1	26.6	27.5	23.4
Pelissier and Kubanka (durum):					
Pelissier.....	1584	10.5	26.6	31.6	22.9
Arnautka.....	1493	10.5	27.6	27.9	22.0
Kubanka.....	1516	6.0	26.5	31.3	21.3
Preston:					
Red Russian.....	4141	8.3	23.0	23.9	18.4
Erivan.....	2397	12.0	19.3	19.5	16.9

RESULTS AT ARCHER, WYO.

At Archer the varietal experiments have included Marquis wheat during the three years, 1913, 1914, and 1915. The annual and average yields are shown in Table XI. The average yield of the highest yielding variety in each group is shown graphically in figure 6.

The results shown in Table XI are much like those obtained at Akron, Colo. The hard red winter wheats outyield any spring wheats, though they exceed the durums by only 1 bushel. The Ghirka Winter, a beardless winter variety, not shown in the table, gave an average acre yield of 18.2 bushels, or nearly 1 bushel more than the Turkey, the best variety of the Crimean group. The durums again outyield all spring common wheats. Among the latter, however, the Marquis leads. It outyields the next best variety of the Fife group, the Ghirka Spring, by 2 bushels, and the best Bluestem variety by 4.5 bushels. However, it exceeds the best of the Preston group by only 0.3 of a bushel.

TABLE XI.—*Annual and average yields of the Marquis and 11 other varieties of wheat grown on the Cheyenne Experiment Farm, Archer, Wyo., 1913 to 1915, inclusive.*

[Experiments conducted in cooperation with the Wyoming State Board of Farm Commissioners.]

Group and variety.	C. I. No.	Yield per acre (bushels).			
		1913	1914	1915	Average.
Fife:					
Marquis.....	3641	9.0	8.4	21.0	12.8
Ghirka Spring.....	1517	9.2	10.0	13.2	10.8
Glyndon.....	2873	5.8	9.6	12.5	9.3
Crimean (winter):					
Turkey.....	1571	10.0	9.8	32.0	17.3
Kharkof.....	1442	9.8	4.7	37.1	17.2
Crimean.....	1559	9.7	3.2	38.6	17.2
Kubanka (durum):					
Beloturka.....	1520	7.7	11.9	28.9	16.2
Kubanka.....	1440	7.5	12.5	25.6	15.2
Preston:					
Red Russian.....	4141	8.3	10.2	19.0	12.5
Preston.....	3698	6.7	9.8	15.3	10.6
Bluestem:					
Haynes (Minn. No. 169).....	2874	4.4	9.0	11.7	8.3
Haynes (Minn. No. 51).....	1505	2.6	5.3	10.7	6.2

RESULTS AT NEWELL, S. DAK.

The experiments at Newell have included the Marquis variety during the 3-year period, 1913 to 1915, inclusive. The annual and average results are shown in Table XII. The yield of the best variety in each group is shown graphically in figure 6.

TABLE XII.—*Annual and average yields of the Marquis and eight other varieties of wheat grown on the Belle Fourche Experiment Farm, Newell, S. Dak., 1913 to 1915, inclusive.*

[Data obtained in cooperation with the South Dakota Agricultural Experiment Station.]

Group and variety.	C. I. No.	Yield per acre (bushels).			
		1913	1914	1915	Average.
Fife:					
Marquis.....	3276	16.8	8.0	50.9	25.2
Power.....	3025	16.6	5.1	43.4	21.7
Glyndon.....	2873	15.8	5.1	39.8	20.2
Crimean (winter):					
Kharkof.....	1442	38.6	28.7	63.8	43.7
Kubanka (durum):					
Pererodka.....	1350	16.7	9.7	58.2	28.2
Kubanka.....	1516	19.1	9.6	54.5	27.7
Arnautka.....	1493	17.1	9.5	54.9	27.2
Preston:					
Preston.....	3081	19.5	7.2	46.9	24.5
Bluestem:					
Haynes.....	3020	14.1	5.1	42.0	20.4

Here, as at the stations previously discussed, the hard winter wheats excel all spring wheats. The Kharkof outyields the Pererodka durum, the highest yielding spring variety, by 55 per cent. Again, the durum wheats outyield all groups of spring common wheats by good margins. The Marquis excels all other varieties of

spring common wheat. It outyields the Preston by only 3 per cent, but the Power and Glyndon by 14 and 20 per cent, respectively, and the Haynes by 19 per cent.

RESULTS AT HIGHMORE, S. DAK.

The Marquis variety has been included in the varietal experiments at Highmore during three years, 1913 to 1915, inclusive. The annual and average yields obtained from the Marquis and eight other varieties are shown in Table XIII. The average yield of the best variety in each group is shown graphically in figure 6.

The Marquis has outyielded all other varieties, both winter and spring, at Highmore during the period specified. The Kubanka and Preston are nearly tied for second place and do not fall far below the Marquis. The Kharkof, the hard winter variety, and the Haynes and three varieties of the Fife group fall from 4 to 11 bushels, or from 22 to more than 100 per cent, below the Marquis in yield. The comparatively high yield of the Marquis variety in 1913 was due to the favorable location of the plat in a low moist spot.

TABLE XIII.—*Annual and average yields of the Marquis and eight other varieties of wheat grown at the Highmore (S. Dak.) substation, 1913 to 1915, inclusive.*

[Experiments conducted in cooperation with the South Dakota Agricultural Experiment Station.]

Group and variety.	C. I. No.	Yield per acre (bushels).			
		1913	1914	1915	Average.
Fife:					
Marquis.....	3641	12.7	13.3	33.3	19.8
Power.....	2989	6.3	8.7	26.7	13.9
Ghirka.....	1517	6.5	11.3	16.7	11.5
Glyndon.....	2873	8.7	7.3	10.0	8.7
Kubanka (durum):					
Kubanka.....	1354	3.3	22.2	30.0	18.5
Do.....	1440	2.0	19.7	33.3	18.3
Preston:					
Preston.....	3081	6.5	12.0	35.8	18.1
Crimean (winter):					
Kharkof.....	1442	2.1	12.5	31.7	15.4
Bluestem:					
Haynes (Minn. No. 51).....	1505	7.7	4.8	22.5	11.7

RESULTS AT EUREKA, S. DAK.

At Eureka the Marquis has been grown in the varietal test during only two years, 1914 and 1915. The annual and average yields are shown in Table XIV. The best yielding variety in each group and the average yield produced by it in the 2-year period are shown graphically in figure 6.

The results show that the Kubanka durum is the highest yielding among the five varieties tested. It outyields the Marquis by 3.5 bushels, or 15.5 per cent. The Marquis ranks second, exceeding the

Preston by 25 per cent and the Dakota Bluestem by 46 per cent. The Turkey, the only variety of hard winter wheat tested, was a complete failure in both years, except when mulched with straw.

TABLE XIV.—*Annual and average yields of the Marquis and four other varieties of wheat grown at the Eureka (S. Dak.) substation during 1914 and 1915.*

[Data obtained in cooperation with the South Dakota Agricultural Experiment Station.]

Group and variety.	C. I. No.	Yield per acre (bushels).			Group and variety.	C. I. No.	Yield per acre (bushels).		
		1914	1915	Average.			1914	1915	Average.
Fife:					Bluestem:				
Marquis.....	3641	9.7	35.5	22.6	Dakota.....	3083	6.6	18.5	12.6
Kubanka (durum):					Crimean (winter):				
Kubanka.....	1440	9.3	42.9	26.1	Turkey.....	3055	0	0	0
Preston:									
Preston.....	3081	10.7	22.9	16.8					

RESULTS AT EDGELEY, N. DAK.

The experiments at Edgeley are conducted independently by the North Dakota Agricultural Experiment Station, and the results shown in Table XV have been made available through the courtesy of the director and other officers of that station. The experiments have included the Marquis during three years, 1913 to 1915, inclusive. The results are given in Table XV, and the yield of the leading variety in each group appears in figure 6.

Winter wheats are not grown at Edgeley. Durum varieties considerably outyield either the Fife or Bluestem groups of spring common wheat. The Marquis wheat excels all other varieties in the Fife and Bluestem groups. It outyields the Power, the next best Fife variety, by over 5 per cent and the Haynes by nearly 10 per cent.

TABLE XV.—*Annual and average yields of the Marquis and seven other varieties of wheat grown at the Edgeley (N. Dak.) substation, 1913 to 1915, inclusive.*

[Data used by courtesy of the North Dakota Agricultural Experiment Station.]

Group and variety.	C. I. No.	N. Dak. No.	Yield per acre (bushels).			
			1913	1914	1915	Average.
Fife:						
Marquis.....		2700	26.6	10.5	32.0	23.0
Power (Sel.).....	3025	312	30.6	7.0	27.9	21.8
Ghirka Spring.....	1517	2013	30.6	9.0	24.6	21.4
Power (Sel. N. Dak. No. 66).....		920	26.9	5.5	31.0	21.1
Kubanka (durum):						
Arnautka.....	1494	778	25.2	15.5	43.4	28.0
Nicaragua.....	2006	543	25.2	15.5	38.2	26.3
Bluestem:						
Haynes (Minn. No. 51).....	3021	779	26.9	5.0	29.9	20.6
American.....		872	25.1	3.5	28.9	19.2

RESULTS AT LANGDON, N. DAK.

At Langdon, as at Edgeley, the experiments are conducted independently by the North Dakota Agricultural Experiment Station, and the results are used here by courtesy of the director and his associates. The experiments have included the Marquis during only two years, 1914 and 1915. The annual and average results are shown in Table XVI and the yield of the leading variety of each group in figure 6.

The results may be seen at a glance. The two durum varieties far excel the Marquis and Glyndon. In the Fife group the Marquis out-yields the Glyndon by 6 bushels, or more than 27 per cent. The yields of Bluestem varieties under the same conditions are not reported.

TABLE XVI.—*Annual and average yields of the Marquis and three other varieties of wheat grown at the Langdon (N. Dak.) substation during 1914 and 1915.*

[Data used by courtesy of the North Dakota Agricultural Experiment Station.]

Group and variety.	C. I. No.	N. Dak. No.	Yield per acre (bushels).			Group and variety.	C. I. No.	N. Dak. No.	Yield per acre (bushels).		
			1914	1915	Average.				1914	1915	Average.
Fife:						Kubanka (durum):					
Marquis.....	-----	2703	18.3	38.1	28.2	Kubanka...	1440	929	31.7	46.1	38.9
Glyndon						Gharnovka..	1443	915	29.7	47.2	38.4
(Minn. No. 163).....	2873	314	12.7	31.7	22.2						

RESULTS AT WILLISTON, N. DAK.

The varietal experiments at Williston have included Marquis wheat during three years, 1913 to 1915, inclusive. The annual and average yields are shown in Table XVII, and the average yield of the leading variety in each group is shown graphically in figure 6.

At Williston, as elsewhere, the durum varieties excel any spring common wheats in yield. The best durum, exceeds that of the Power, the best spring common, by 4.6 bushels, or nearly 14 per cent. Considering only the common wheats, the rank of the groups is Fife, Bluestem, Preston, and Crimean (winter), in the order named. Among the Fife varieties, the Power outyields the Marquis by 1 bushel, or 2.5 per cent. The Glyndon, in the Fife group, and the Dakota, a Bluestem variety, almost exactly equal the Marquis in yield. The yields of the winter-wheat varieties are very low.

The comparatively low yield of the Marquis in 1915 was due to damage by a late spring frost. The plants were about 8 inches tall at the time. Not only at Williston but also at other points in the State the Marquis seemed to be more seriously injured than other varieties.

TABLE XVII.—*Annual and average yields of the Marquis and 12 other varieties of wheat grown at the Williston (N. Dak.) substation, 1913 to 1915, inclusive.*

[Data obtained in cooperation with the North Dakota Agricultural Experiment Station.]

Group and variety.	C. I. No.	Yield per acre (bushels).				Group and variety.	C. I. No.	Yield per acre (bushels).			
		1913	1914	1915	Average.			1913	1914	1915	Average.
Fife:						Bluestem:					
Marquis.....	3641	29.0	52.5	40.6	40.7	Dakota.....	3083	30.7	47.5	44.6	40.9
Power.....	3697	28.7	51.3	45.1	41.7	Haynes.....	2874	30.0	42.5	42.9	38.5
Glyndon.....	2873	28.2	49.2	44.1	40.5	Preston:					
Red Fife.....	3694	28.7	47.9	43.9	40.2	Preston.....	3698	25.0	46.3	43.4	38.2
Kubanka (durum):						Winter:					
Taganrog selection.....	1570	35.0	54.6	49.4	46.3	Buffum No. 17.....	3330	15.6	17.1	6.4	13.0
Kubanka.....	1440	33.0	53.8	47.3	44.7	North Dakota No. 1997.....	3084	13.1	15.8	6.1	11.7
Arnautka.....	3693	34.7	47.2	45.5	42.5	Beloglina.....	1543	7.8	10.0	12.8	10.2

RESULTS AT DICKINSON, N. DAK.

Marquis wheat has been grown at the Dickinson substation during three years, 1913 to 1915, inclusive. The annual and average yields obtained from this and other varieties are shown in Table XVIII. The average yield of the leading variety in each group is shown graphically in figure 6.

The results obtained are nearly the same as those at Williston. The durum wheats lead by a wide margin. The Marquis is the highest yielding variety of common wheat, and the Kubanka No. 8 excels it by nearly 35 per cent. The groups of common wheat rank in the same order as at Williston, namely, Fife, Bluestem, Preston, and Crimean (winter). The Marquis outyields the Rysting, the next best Fife variety, by 1.7 bushels, or 6 per cent, and the Preston by 2.7 bushels, or 11 per cent, while it exceeds the Crossbred Bluestem by 3.4 bushels, or 14 per cent. The winter wheats are not successfully grown in North Dakota.

TABLE XVIII.—*Annual and average yields of the Marquis and 12 other varieties of wheat grown at the Dickinson (N. Dak.) substation, 1913 to 1915, inclusive.*

[Data obtained in cooperation with the North Dakota Agricultural Experiment Station.]

Group and variety.	C. I. No.	Yield per acre (bushels).				Group and variety.	C. I. No.	Yield per acre (bushels).			
		1913	1914	1915	Average.			1913	1914	1915	Average.
Fife:						Preston:					
Marquis.....	3641	24.2	14.0	32.8	23.7	Preston.....	3081	25.2	12.9	24.8	21.0
Rysting.....	3022	28.1	12.4	25.6	22.0	Preston.....	3328	26.2	7.2	25.9	19.8
Red Fife.....	3329	28.3	10.2	25.3	21.3	Bluestem:					
Ghirka Spring.....	1517	26.6	11.3	24.3	20.7	Crossbred.....	3314	27.1	10.1	23.7	20.3
Kubanka (durum):						Haynes.....	2874	24.8	8.3	22.9	18.7
Kubanka No. 8.....	4063	31.2	13.0	51.5	31.9	Crimean (winter):					
Kubanka.....	1440	26.7	14.2	48.5	29.8	Beloglina.....	1543	9.1	9.2	0	6.1
Arnautka 6P1.....	4064	30.9	11.6	44.8	29.1	Kharkof.....	1583	3.6	11.0	0	4.9

RESULTS AT MOCCASIN, MONT.

The varietal experiments at Moccasin have included Marquis wheat during the 3-year period, 1913 to 1915, inclusive. The annual and average yields obtained are given in Table XIX. The average yield of the leading variety in each group is shown in figure 6.

The hard red winter wheats of the Crimean group outyield all spring wheats at Moccasin by a margin of over 6 bushels per acre. Among the spring wheats the durum do not outrank the spring common wheats, as they have done at most of the other stations; in fact, the best varieties of durum, Fife, and Preston wheats are practically equal in yield. The Marquis leads the Fife varieties by a margin of over 5 per cent. The leading variety of durum wheat and the leading variety of the Preston group of common wheat outyield the Marquis, however, by the narrow margins of 1 and 3 per cent, respectively.

TABLE XIX.—*Annual and average yields of the Marquis and 11 other varieties of wheat grown at the Judith Basin substation, Moccasin, Mont., 1913 to 1915, inclusive.*

[Data obtained in cooperation with the Montana Agricultural Experiment Station.]

Group and variety.	C. I. No.	Yield per acre (bushels).				Group and variety.	C. I. No.	Yield per acre (bushels).			
		1913	1914	1915	Average.			1913	1914	1915	Average.
Fife:						Preston:					
Marquis.....	3641	33.5	23.7	42.3	33.2	Fretes.....	1596	35.2	25.1	42.5	34.3
Power.....	3697	28.7	24.1	41.0	31.3	Preston.....	2959	29.2	22.4	41.6	31.1
Rysting.....	3022	26.7	23.0	40.6	30.1	Pelissier and Ku-					
Glyndon.....	2873	20.0	22.7	41.0	27.9	banka (durum):					
Crimean (winter):						Pelissier.....	1584	32.0	26.5	42.2	33.6
Kharkof.....	1583	31.1	30.3	61.3	40.9	Pererodka.....	1350	32.0	25.3	40.1	32.5
Do.....	1442	33.1	32.1	56.6	40.6	Kubanka.....	1440	30.7	23.0	40.7	31.5
Crimean.....	1559	35.3	30.8	54.1	40.1						

CONCLUSIONS.

The graphic portrayal in figure 6 and the facts given in Tables IX to XIX, inclusive, show that winter wheat is decidedly better than any spring wheat in much of this section. In central South Dakota and North Dakota, however, winter wheat can not be grown successfully.

Among spring wheats, the durum outyielded all the groups of common wheat at all of these stations, except Moccasin, Mont., and Highmore, S. Dak. At all the stations except Highmore, in central South Dakota, the durum wheats outyielded the Marquis variety. At Highmore the high yield of the Marquis wheat was due to the specially favorable location of the Marquis plat in a low spot in 1913. At Moccasin, Mont., however, the yields of the Marquis and the best durum variety were about equal.

The Marquis outyields the other Fife wheats or equals them in yield at all these stations except Williston, N. Dak., and Akron, Colo. At Williston the Power and at Akron the Ghirka Spring outyield the Marquis variety, but by only 2.5 and 4 per cent, respectively.

The Marquis outyields the Bluestem wheats at all stations except Williston, N. Dak., where the Dakota Bluestem very slightly exceeds it. The Marquis was damaged more than the other varieties by a late spring frost at Williston in 1915. This caused the lower average yield at this point.

The Marquis outyielded all varieties of the Preston group everywhere except at Moccasin, Mont., and Akron, Colo. At Moccasin the Fretes and at Akron the Red Russian outyielded the Marquis, but by only about 3 per cent in each case.

From these facts it is seen—

(1) That winter varieties are best where they can be grown in the northern section of the Great Plains area.

(2) That durums are better than any spring common wheats in this section.

(3) That the Marquis variety is better than any of the spring common wheats at some stations and about as good as any at most stations. The Marquis is a safe variety to grow anywhere in this section when spring wheat is to be grown.

The Marquis variety is especially well adapted to central South Dakota. Here drought and rust often reduce the yields of later maturing varieties. The Preston ("Velvet Chaff"), a bearded wheat, is now the leading variety in that district. The Marquis is beardless and a better yielder, as well as a better milling wheat.

Rust and drought are not so frequent in North Dakota and Montana. The earliness of the Marquis variety gives it an advantage when they do occur. The later maturing Fife and Bluestem varieties may give as high average yields in a longer series of years.

RESULTS IN THE WESTERN BASIN AND COAST AREAS.

The dry lands of the States west of the Rocky Mountains are included under this heading. The different sections represented are known as the Great Basin, the Snake River basin, the Harney Valley, the Columbia Basin, and the Sacramento Valley. They include, therefore, the States of Utah, Idaho, Washington, Oregon, Nevada, and northern California.

Marquis wheat has been introduced commercially at a few places. Several carloads of seed are known to have been sold in the Columbia Basin counties of Washington. Similar introductions may have occurred in the Snake River basin also, but no record of such action is known. It is doubtful whether the variety has been introduced elsewhere in these areas. No statistics of production are available, but the total quantity must be very small.

Varietal experiments with Marquis wheat have been conducted on nonirrigated land at five experiment stations west of the Rocky Mountains. These stations include Nephi, Utah, Aberdeen, Idaho, and Burns, Oreg., where the experiments have included the Marquis variety during two years; Moro, Oreg., where the experiments have continued during three years; and Davis, Cal., where the variety has been grown but a single year. The locations of these stations

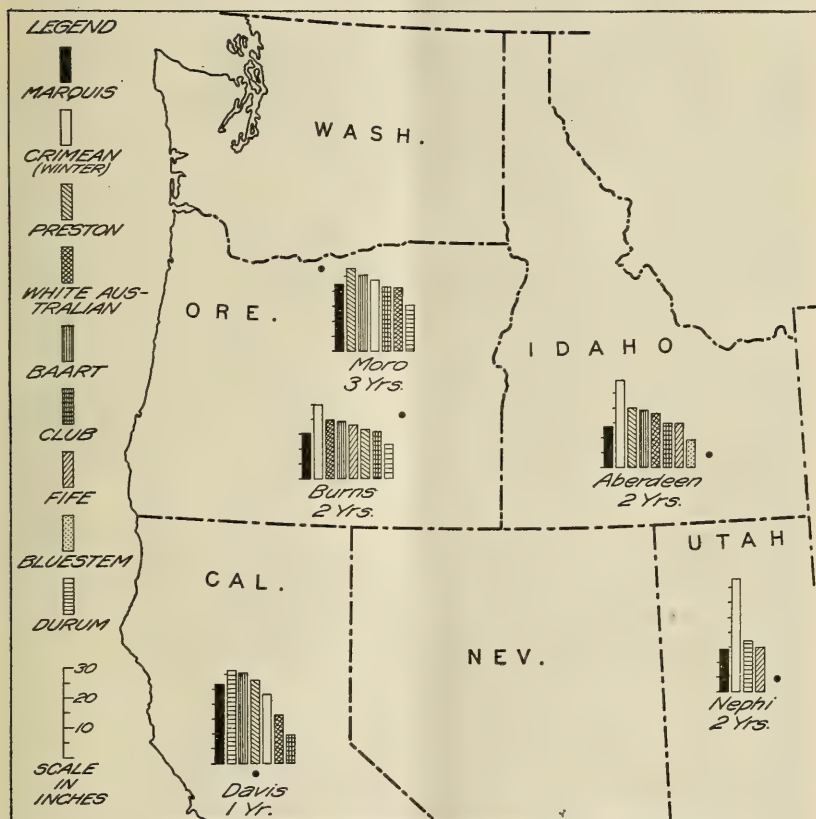


FIG. 7.—Diagram showing the average yields of the Marquis and the leading variety in each of several different groups of wheat at five dry-land stations west of the Rocky Mountains during one, two, or three of the years 1913 to 1915, inclusive.

and the average yield of the Marquis and also of the leading variety in each of several groups of wheat are shown in figure 7. The same data and those on still other varieties will be found in Tables XXI to XXV, inclusive. In figures 8 and 9 are shown heads and kernels of varieties representing the White Australian, Baart, and Little Club groups of soft white wheat, all of which are commercially important wheats in this section.

The climate of these basins and valleys is usually regarded as semiarid to arid. Table XX shows the elevation of each station and the recorded annual and seasonal precipitation during the years

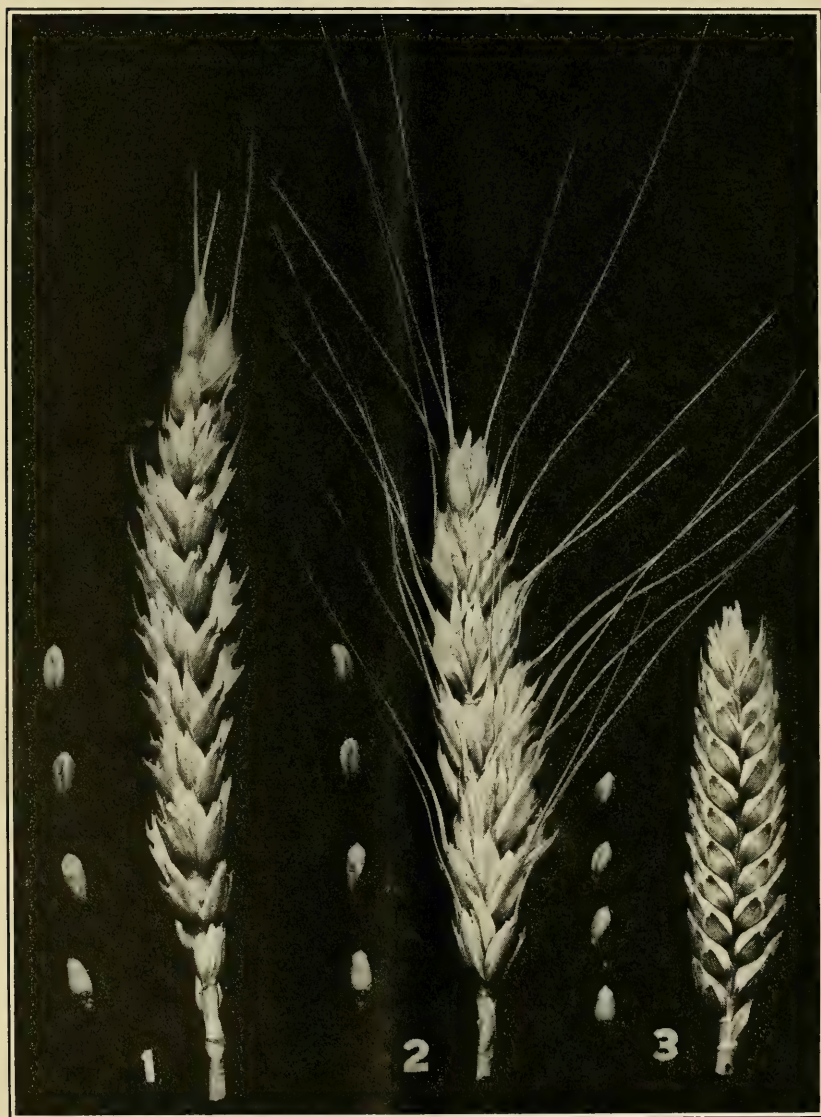


FIG. 8.—Heads and kernels of three varieties of soft white wheat, natural size: 1, Palouse Bluestem; 2, Early Baart; 3, Little Club.

when the experiments herein reported were in progress, so far as the data are available.

These areas are characterized by low precipitation. Most of it falls during the autumn, winter, and spring months instead of during

the summer, as in the Great Plains area. This makes the seasonal rainfall small in proportion to the total, as will be noted in Table XX. For this reason, among others, winter wheats are more profitable and more extensively grown in these sections than spring varie-

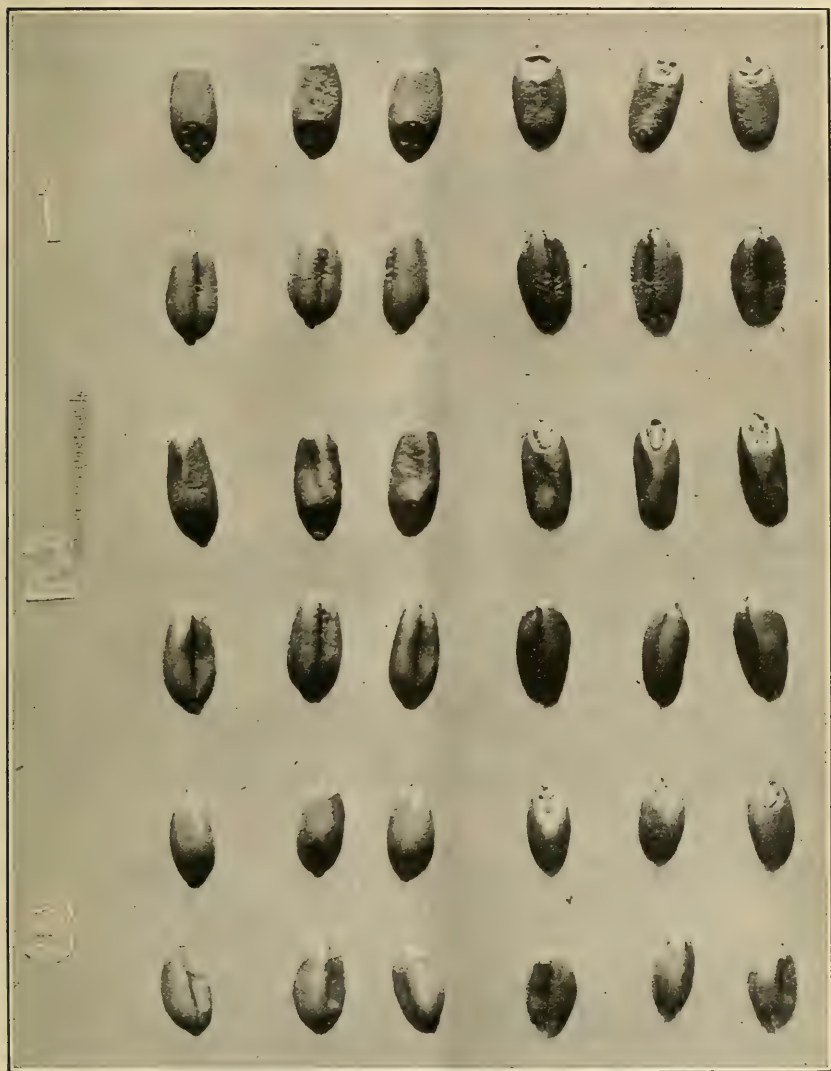


FIG. 9.—Kernels of three varieties of soft white wheat, shown in four different positions, twice natural size: 1, Palouse Bluestem; 2, Early Baart; 3, Little Club.

ties. Crop production is governed almost wholly by the quantity and distribution of the annual rainfall.

The elevation of these sections varies greatly. It is 6,000 feet or more in places, as in the Juab Valley, near Nephi, Utah, and in the

upper part of the Snake River Basin. Most of the surface lies at elevations of 4,000 to 5,000 feet. The Columbia Basin is much lower, scarcely exceeding 2,000 feet, while the Sacramento Valley of California reaches sea level at its lower end. Wind velocities are rather low in most of these areas. The summers are warm and evaporation fairly high. The growing season is short at the higher elevations. In the Harney Valley frosts occur during the summer months. Here, as elsewhere, early varieties of spring wheat have an advantage over midseason or late varieties.

TABLE XX.—*Altitude and annual and seasonal precipitation at five experiment stations in the arid western basin and coast areas.*

Station.	Altitude.	Precipitation (inches).							
		Annual.				Seasonal. ¹			
		1913	1914	1915	Average.	1913	1914	1915	Average.
Nephi, Utah.....	<i>Feet.</i> 6,000	.....	14.40	13.63	14.01	.....	5.85	5.54	5.70
Aberdeen, Idaho.....	4,400	.....	9.86	8.29	9.08	.....	4.20	3.91	4.06
Burns, Oreg.....	4,100	.....	8.50	6.82	7.66	.....	4.28	3.06	3.67
Moro, Oreg.....	1,800	12.17	11.32	14.86	12.78	4.30	3.56	3.64	4.50
Davis, Cal.....	51	.....	.....	21.02	.....	.....	.....	14.43	.....

¹ The record for seasonal precipitation includes the months of April, May, June, and July at Aberdeen and Moro. At Nephi the record is for the three months, April, May, and June, and at Burns for the five months, April, May, June, July, and August. At Davis the record is for six months, January to June, inclusive.

RESULTS AT NEPHI, UTAH.

At the Nephi substation the cooperative experiments have included the Marquis variety for only two years, 1914 and 1915. The annual and average yields are shown in Table XXI. The average yield of the leading variety in each of the three groups is shown graphically in figure 7.

TABLE XXI.—*Annual and average yields of the Marquis and three other varieties of wheat grown at the Nephi (Utah) substation during 1914 and 1915.*

[Data obtained in cooperation with the Utah Agricultural Experiment Station.]

Group and variety.	C. I. No.	Yield per acre (bushels).		
		1914	1915	Average.
Fife:				
Marquis.....	3641	a 12.4	16.3	14.4
Ghirka Spring.....	1517	11.2	19.0	15.1
Crimean (winter):				
Turkey.....	2998	43.0	32.6	37.8
Crimean.....	1437	40.3	29.9	35.1
Durum:				
Adjini.....	1594	19.0	15.3	17.2
Kubanka.....	1440	15.7	18.2	17.0

a Yield in 1914 from a single row 121 feet long.

The data show the marked superiority of the hard red winter wheats over any spring wheats at the Nephi substation. The Turkey variety surpasses the Marquis by 165 per cent and the leading spring wheat by over 100 per cent. The durum varieties exceed the Marquis in yield by nearly 20 per cent. In the Fife group the Marquis is exceeded by the Ghirka Spring by nearly 5 per cent. The Marquis is thus the lowest yielder among the six varieties considered. The yield of the Marquis in 1914 is from a 121-foot row; in 1915 it is the average of four tenth-acre plats.

RESULTS AT ABERDEEN, IDAHO.

The cooperative varietal experiments conducted at Aberdeen, Idaho, have included Marquis wheat only during the last two years, 1914 and 1915. The annual and average yields of the Marquis and numerous other varieties are shown in Table XXII. The average yield of the best variety in each of the seven groups is shown graphically in figure 7.

The outstanding fact shown by Table XXII is that here again the varieties of the hard red winter or Crimean group of wheats strongly outyield all spring wheats. The best variety exceeds the Marquis by 110 per cent. The Fretes, Early Baart, and Palouse Bluestem, representing three different groups of spring wheat, outyield the Marquis by 44, 39, and 31 per cent, respectively. Even the Little Club excels the Marquis in yield by nearly 8 per cent. Considering finally the Fife group, the Ghirka Spring exceeds the Marquis by 8 per cent, while the Power almost equals it in yield.

TABLE XXII.—*Annual and average yields of the Marquis and 13 other varieties of wheat grown at the Aberdeen (Idaho) Branch Experiment Station during 1914 and 1915.*

[Data obtained in cooperation with the Idaho Agricultural Experiment Station.]

Group and variety.	C. I. No.	Yield per acre (bushels).			Group and variety.	C. I. No.	Yield per acre (bushels).		
		1914	1915	Average.			1914	1915	Average.
Fife:					Baart:				
Marquis.....	3276	21.5	6.3	13.9	Early Baart.....	1697	31.1	7.5	19.3
Ghirka Spring.....	1517	26.1	4.9	15.0	White Australian:				
Power.....	3697	22.4	4.5	13.4	Palouse Bluestem..	4067	27.5	9.0	18.2
Rysting.....	3022	20.1	3.6	11.8	Defiance.....	3703	19.7	6.3	13.0
Crimean (winter):					Dicklow.....	3663	18.3	6.3	12.0
Turkey.....	1571	38.5	20.2	29.3	Little Club:				
Kharkof.....	1442	29.3	21.1	25.2	Little Club.....	4066	22.9	7.2	15.0
Turkey.....	2998	25.6	22.5	24.1	Bluestem:				
Preston:					Haynes.....	2874	13.2	5.4	9.3
Fretes.....	1596	30.2	10.8	20.0					

RESULTS AT BURNS, OREG.

The Marquis variety has been included in the cooperative varietal experiment at Burns during two years, 1914 and 1915. The annual and average yields of the Marquis and other varieties, representing seven different groups of wheats, are shown in Table XXIII. The average yield of the highest yielding variety in each group is shown graphically in figure 7.

The results show that all the varieties in all the groups except the two durum varieties outyielded the Marquis by percentages varying from nearly 5 to over 64. The hard red winter wheats are again the highest yielders, though not so markedly superior as in Utah or even in Idaho. The Palouse Bluestem and Early Baart excel the Marquis here by more than 29 and 27 per cent, respectively. Two varieties of the Preston group, the Fretes and Erivan, outyield Marquis by nearly 10 per cent, while the Little Club excels it by about 5 per cent. In the Fife group, the Ghirka Spring again outyields the Marquis, this time by 19 per cent.

TABLE XXIII.—*Annual and average yields of the Marquis and 10 other varieties of wheat grown at the Harney Branch Station, Burns, Oreg., during 1914 and 1915.*

[Experiments conducted cooperatively with the Oregon Agricultural Experiment Station.]

Group and variety.	C. I. No.	Yield per acre (bushels).			Group and variety.	C. I. No.	Yield per acre (bushels).		
		1914	1915	Average.			1914	1915	Average.
Fife:					Preston:				
Marquis.....	4158	9.3	21.3	15.2	Fretes.....	1596	13.3	20.0	16.7
Ghirka Spring.....	1517	15.7	20.5	18.1	Erivan.....	2397	12.7	20.3	16.5
Crimean (winter):					Little Club:				
Turkey.....	1558	19.3	30.7	25.0	Little Club.....	4066	13.7	18.0	15.9
Kharkof.....	1442	12.0	27.1	19.6	Kubanka (durum):				
White Australian:					Kubanka.....	2246	8.0	15.3	11.7
Palouse Bluestem...	4067	16.7	22.7	19.7	Marouani.....	1593	7.2	16.0	11.6
Baart:									
Early Baart.....	1697	18.2	20.5	19.4					

RESULTS AT MORO, OREG.

At the Eastern Oregon Dry-Farming substation at Moro the cooperative varietal experiments have included the Marquis wheat during the 3-year period, 1913 to 1915, inclusive. The annual and average yields of the Marquis and numerous other varieties are shown in Table XXIV. The average yield of the best variety representing each group is shown graphically in figure 7.

The tabulated data show that the average yields of all groups except the durum lie between 21 and 28 bushels per acre. The hard red winter wheat here occupies about the middle of the scale, with a yield of 24 bushels per acre. At Moro the Marquis outyielded the Palouse Bluestem and Little Club about 5 per cent, but is excelled by the Early Baart by nearly 14 per cent. The highest yielding

variety of all is the Koola, of the Preston group, a spring wheat not yet grown commercially. The Koola outyielded the Marquis by 23 per cent in the 3-year test.

TABLE XXIV.—*Annual and average yields of the Marquis and eight other varieties of wheat grown at the Eastern Oregon Dry-Farming substation, Moro, Oreg., 1913 to 1915, inclusive.*

[Data obtained in cooperation with the Oregon Agricultural Experiment Station.]

Group and variety.	C. I. No.	Yield per acre (bushels).			
		1913	1914	1915	Average.
Fife:					
Marquis.....	4158	22.1	22.5	23.1	22.6
Preston:					
Koola.....	2203-2	25.8	24.5	33.2	27.8
Baart:					
Early Baart.....	1697	25.0	25.5	26.6	25.7
Crimean (winter):					
Turkey.....	1558	24.0	27.5	20.6	24.0
Little Club:					
Little Club.....	4068	19.6	19.2	26.0	21.6
White Australian:					
Palouse Bluestem.....	4067	19.4	20.9	24.0	21.4
Kubanka (durum):					
Kubanka.....	1440	13.6	15.0	18.0	15.5

RESULTS AT DAVIS, CAL.

The experiments at Davis are conducted independently by the Agricultural Experiment Station of California, and the data are made available here through the courtesy of the director of the station and his associates. Marquis wheat has been grown there only in the year 1915. The yields of this and numerous other varieties, as well as the bushel weight of the seed, are shown in Table XXV. The yield of the highest yielding variety in each group is shown graphically in figure 7.

It will be appreciated readily that the yields of a single year afford no basis for conclusions. Three durum varieties and two spring common wheats, the Early Baart and Fretes, outyielded the Marquis. The season was abnormal, as may be seen by the low bushel weights, and rust was very prevalent.

In transmitting the data, Prof. John W. Gilmore writes as follows:

The yields obtained in the variety trials with wheat in plats this season were very low, due largely to unfavorable weather conditions. The late spring rains caused the grain to lodge badly and also greatly increased the rust, so that the percentages of lodging and of rust infection this season were abnormally high. Then, too, the hot north winds which occurred during the ripening period caused the grain to shrivel badly instead of ripening as it should. The degree to which the grain was infected may be observed from the low weight per bushel of all varieties this season. * * *

In comparing the results this season with past performances, it is further worthy of note that the yield of the White Australian checks was abnormally low in comparison with the other varieties. * * * The winter wheats this season gave much better results than usual, in comparison with the other varieties.

TABLE XXV.—*Yield per acre and weight per bushel of the Marquis and 13 other varieties of wheat grown at Davis, Cal., in 1915.*

[Data used by courtesy of the California Agricultural Experiment Station.]

Group and variety.	C. I. No.	Yield per acre.	Weight per bushel.
Fife:		<i>Bushels.</i>	<i>Pounds.</i>
Marquis.....		26.8	55.0
Unclassified durum:			
Marouani.....	1593	31.5	57.0
Durum X Club.....	4247	30.8	49.0
Velvet Don.....	2247-1	29.5	55.0
Baart:			
Imported Early Baart.....		30.7	50.0
Early Baart.....	1697	21.3	51.5
Propo.....	1970	13.8	52.0
Preston:			
Fretes.....	1596	28.2	54.0
Chul.....	2227	15.7	47.0
Crimean:			
Turkey.....		23.3	55.5
White Australian:			
Imported White Australian.....		16.3	46.0
White Australian ¹	3019	15.3	41.7
California Gem.....	4248	8.0	37.0
Little Club:			
Little Club.....	3018	9.7	42.0

¹ Average of 16 check plats.

CONCLUSIONS.

The data in Tables XXI to XXV, inclusive, and in figure 7 show that the Marquis variety has not proved a high yielder at any station west of the Rocky Mountains. At three stations in Utah, Idaho, and Oregon, winter wheats outyield all spring wheats. At all five stations, other spring wheats outyield the Marquis. It is not as good, on the average, as the Palouse Bluestem, Early Baart, Fretes, or Ghirka Spring. It also is not as good as several of the new wheats which have been tested at these western stations but are not yet grown commercially. Marquis wheat is not recommended for any district west of the Rocky Mountains.

RESULTS IN IRRIGATED DISTRICTS.

Irrigated farming is confined to the valleys more or less adjacent to the mountains of the Western States. So far as known, Marquis wheat has not been grown commercially under irrigation.

Experiments to determine the value of Marquis wheat under irrigation conditions have been conducted at four different points. Two of these are east and two west of the Rocky Mountains. The stations are Newell, S. Dak.; Huntley, Mont.; Aberdeen, Idaho, and Fallon, Nev. The location of these four stations and the average yields of Marquis wheat and of the best variety in each of several groups of wheat are shown graphically in figure 10. The annual and average yields of the Marquis and several other varieties will be found in Tables XXVI to XXIX inclusive.

The normal rainfall at these points is of little importance, since irrigation water is supplied. One effect of the abundant water supply, however, is to lengthen the period required by the plant to reach maturity. Hence, early varieties are desirable where the elevation is sufficient to shorten the frost-free period. The altitude at Newell, S. Dak., as shown in Table VIII, is 2,950 feet above sea level. The altitude at Huntley, Mont., is 3,000 feet. The altitude of Aberdeen, Idaho, shown in Table XX, is 4,400 feet, while Fallon,

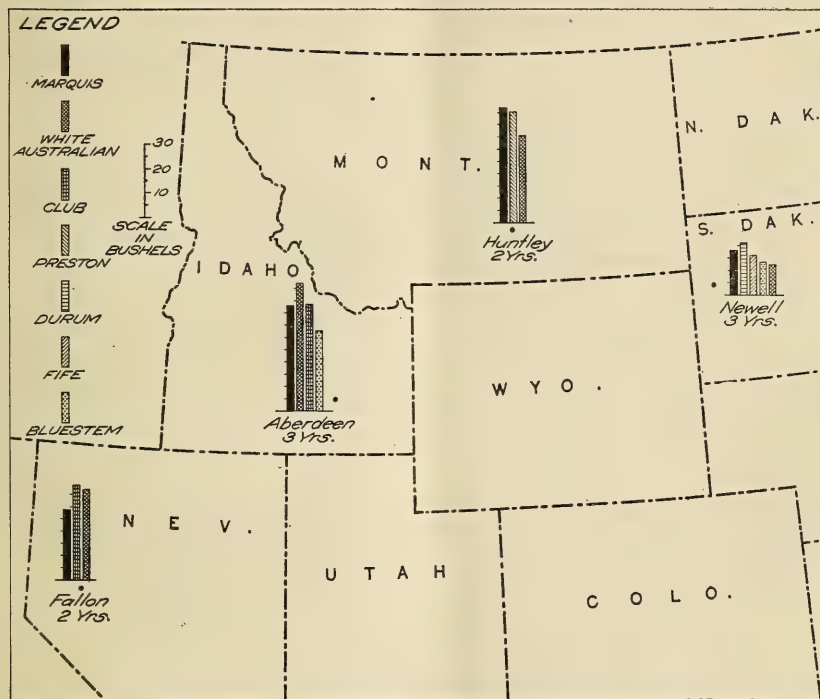


FIG. 10.—Diagram showing the average yields of the Marquis and the leading variety in each of several different groups of wheat under irrigation at four western stations in either two or three of the years 1913 to 1915, inclusive.

Nev., has an altitude of 3,965 feet. The growing season is of only medium length under these conditions. Sometimes it is much shortened by the occurrence of early autumn frosts. Early-maturing varieties, therefore, are best adapted to the conditions obtaining at these stations.

RESULTS AT NEWELL, S. DAK.

The experiments with wheat under irrigation at Newell, S. Dak., are conducted in cooperation with the Office of Western Irrigation Agriculture. Marquis wheat has been included in the varietal experiments during the 3-year period, 1913 to 1915, inclusive. The annual

and average yields obtained from the Marquis and four other varieties of wheat are given in Table XXVI. The average yield of each variety is shown graphically in figure 10.

The Marquis wheat has been compared with durum wheats and with varieties of common wheats of the Fife, Bluestem, and White Australian groups. The last named group consists of soft white wheats, extensively grown west of the Rocky Mountains and represented at Newell by the Defiance variety. The Kubanka durum outyields the Marquis by over 20 per cent. The Marquis, however, outyields the Power by 11 per cent, and the Haynes and Defiance by 25 and 30 per cent, respectively. The Marquis has been compared with winter wheat only in 1915, when the Kharkof, a Crimean or hard red winter wheat, yielded nearly four times as much as the Marquis.

TABLE XXVI.—*Annual and average yields of the Marquis and four other varieties of wheat grown under irrigation on the Belle Fourche Experiment Farm, Newell, S. Dak., 1913 to 1915, inclusive.*

[Data obtained in cooperation with the Office of Western Irrigation Agriculture.]

Group and variety.	C. I. No.	Yield per acre (bushels).			
		1913	1914	1915	Average.
Fife:					
Marquis.....	3276	18.3	18.3	18.0	18.2
Power.....	3025	17.0	17.0	14.7	16.2
Kubanka (durum):					
Kubanka.....	1440	18.6	22.8	22.0	21.7
Bluestem:					
Haynes.....	2874	14.2	15.4	11.5	13.7
White Australian:					
Defiance.....	3703	11.7	18.0	8.0	12.6
Crimean (winter):					
Kharkof.....	1583	.....	.....	66.3	.....

RESULTS AT HUNTLEY, MONT.

The experiments at Huntley are conducted cooperatively by the Office of Western Irrigation Agriculture and the Montana Agricultural Experiment Station. The data here presented have been furnished by the Agriculturist in Charge of the Office of Western Irrigation Agriculture. The Marquis variety has been grown in varietal experiments during only two years, 1913 and 1914. The annual and average yields are given in Table XXVII. The average yield of the best variety in each group is shown graphically in figure 10.

At the Huntley station the Marquis variety has been compared only with spring common wheats. It has outyielded Pringle Champlain by 4 per cent; Stanley, a beardless variety with brown glumes, by 25 per cent; and Dicklow, by 32 per cent.

TABLE XXVII.—*Annual and average yields of the Marquis and four other varieties of wheat grown under irrigation on the Huntley (Mont.) Experiment Farm during 1914 and 1915.*

[Data furnished by the Office of Western Irrigation Agriculture.]

Group and variety.	Yield per acre (bushels).			Group and variety.	Yield per acre (bushels).		
	1913	1914	Average.		1913	1914	Average.
Fife:				Unclassified:			
Marquis.....	30.8	63.3	47.0	Stanley.....	27.1	47.9	37.5
Preston:				White Australian:			
Pringle Cham-				Dicklow.....	29.4	41.9	35.6
plain.....	35.4	54.9	45.1	Defiance.....	.....	56.0	.....

RESULTS AT ABERDEEN, IDAHO.

The Marquis variety has been grown under irrigation at Aberdeen during a 3-year period, 1913 to 1915, inclusive. The annual and average yields are shown in Table XXVIII. The average yield of the best variety in each group is shown graphically in figure 10.

Among the six varieties tested, the Marquis ranks fifth, outyielding only the Haynes. The yield of the Little Club is practically the same as that of the Marquis. The three varieties in the White Australian group, however, outyield the Marquis by 9, 14, and 31 per cent, respectively. The Defiance is commonly grown under irrigation in the Western States, while the Palouse Bluestem is the standard variety of spring wheat on the dry-land farms.

TABLE XXVIII.—*Annual and average yields of the Marquis and five other varieties of wheat grown under irrigation on the Aberdeen Experiment Farm, Aberdeen, Idaho, 1913 to 1915, inclusive.*

[Data obtained in cooperation with the Idaho Agricultural Experiment Station.]

Group and variety.	C. I. No.	Yield per acre (bushels).			
		1913	1914	1915	Average.
Fife:					
Marquis.....	3276	33.3	38.9	56.7	43.0
White Australian:					
Dicklow.....	3663	61.5	38.0	56.7	52.1
Defiance.....	3703	55.6	43.5	47.7	48.9
Palouse Bluestem.....	4067	42.0	38.0	62.1	47.0
Little Club:					
Little Club.....	4223	41.3	41.2	47.7	43.4
Bluestem:					
Haynes.....	2874	36.0	27.4	35.1	32.8

RESULTS NEAR FALLON, NEV.

The varietal experiments with wheat on the Carson-Truckee Reclamation Project are conducted in cooperation with the Office of Western Irrigation Agriculture. In 1914 the experiments were conducted on the farm of L. W. Langford, and in 1915 on the farm

of A. R. Merritt. The results obtained are shown in Table XXIX. The average yield of the best variety in each group is shown graphically in figure 10. The two farms used for these experiments are about 20 miles apart. The results obtained in the two different years are not directly comparable. Since they agree fairly well, however, they have been averaged in Table XXIX and in figure 10.

Only spring common wheats have been compared with the Marquis in Nevada. Table XXIX shows that the Palouse Bluestem, Dicklow, and Little Club all outyielded the Marquis by large margins. The overyields amount to 22, 28, and 33 per cent, respectively.

TABLE XXIX.—*Annual and average yields of the Marquis and three other wheats grown under irrigation on the Truckee-Carson Reclamation Project near Fallon, Nev., during 1914 (farm of L. W. Langford) and 1915 (farm of A. R. Merritt).*

[Data obtained in cooperation with the Office of Western Irrigation Agriculture.]

Group and variety.	C. I. No.	Yield per acre (bushels).			Group and variety.	C. I. No.	Yield per acre (bushels).		
		1914	1915	Average.			1914	1915	Average.
Fife:					White Australian:				
Marquis.....	3641	18.3	39.4	28.9	Dicklow.....	3663	30.7	43.2	37.0
Little Club:					Palouse Bluestem...	4067	30.1	40.5	35.3
Little Club.....	4066	31.8	45.2	38.5					

CONCLUSIONS.

In Idaho and Nevada the soft white spring wheats, Dicklow, Defiance, Palouse Bluestem, and Little Club, all have outyielded the Marquis under irrigation. The Marquis wheat is not a profitable variety to grow under irrigation west of the Rocky Mountains.

In western South Dakota and in Montana the Marquis has given good results in comparison with other varieties of spring common wheat. The few data available indicate that it does not yield as well as the Kubanka durum and the Kharkof winter wheat.

SUMMARY OF YIELD DATA.

For convenience of comparison a summary of the average yields is presented in Table XXX. This summary contains the average yield of the most productive variety in each group at each station where it was grown. In all, 23 stations are represented. There are 25 different sets of experiments, however, as the varieties were grown under both nonirrigated and irrigated conditions at two stations. The Marquis and representatives of eight other groups are included.

The average yields of the same varieties at the same stations are also expressed in Table XXX in percentages of the yields of the Marquis variety. Arranging the data in this form makes comparison still more easy.

TABLE XXX.—Average yields of the Marquis and of the highest yielding variety in eight different groups of wheat grown at 23 experiment stations in the western United States under humid, semiarid, arid, and irrigated conditions during part or all of the three-year period from 1913 to 1915, inclusive.

YIELDS PER ACRE OF THE BEST VARIETY IN EACH GROUP (BUSHELS).

Division and station.	Num- ber of years grown.	Mar- quis.	Cri- mean (win- ter).	Ku- banka or Pe- lissier (du- rum).	Fife.	Blue- stem.	Pres- ton.	White Aus- tralian.	Baart.	Little Club.
Northern Prairie States:										
Ames, Iowa.....	2	16.5	41.2	-----	12.2	12.9	13.6	-----	-----	-----
Lincoln, Nebr.....	3	27.4	35.3	-----	-----	-----	26.0	-----	-----	-----
Brookings, S. Dak.....	3	23.9	36.1	20.1	12.0	15.7	19.5	-----	-----	-----
St. Paul, Minn.....	3	39.9	^a 52.4	34.2	38.3	33.5	38.9	-----	-----	-----
Crookston, Minn.....	3	28.4	-----	26.8	-----	20.0	21.3	-----	-----	-----
Northern Great Plains area:										
North Platte, Nebr.....	3	10.4	18.8	12.2	-----	-----	4.2	-----	-----	-----
Akron, Colo.....	3	17.9	24.3	22.9	18.6	-----	18.4	-----	-----	-----
Archer, Wyo.....	3	12.8	17.3	16.2	10.8	8.3	12.5	-----	-----	-----
Newell, S. Dak.....	3	25.2	43.7	28.2	21.7	20.4	24.5	-----	-----	-----
Highmore, S. Dak.....	3	19.8	15.4	18.5	13.9	11.7	18.1	-----	-----	-----
Eureka, S. Dak.....	2	22.6	0	26.1	-----	12.6	16.8	-----	-----	-----
Edgeley, N. Dak.....	3	23.0	-----	28.0	21.8	20.6	-----	-----	-----	-----
Langdon, N. Dak.....	2	28.2	-----	38.9	22.2	-----	-----	-----	-----	-----
Williston, N. Dak.....	3	40.7	11.7	46.3	41.7	40.9	38.2	-----	-----	-----
Dickinson, N. Dak.....	3	23.7	6.1	31.9	22.0	20.3	21.0	-----	-----	-----
Moccasin, Mont.....	3	33.2	40.9	33.6	31.3	-----	34.5	-----	-----	-----
Western basin and coast areas:										
Nephi, Utah.....	2	14.4	37.8	17.2	15.1	-----	-----	-----	-----	-----
Aberdeen, Idaho.....	2	13.9	29.3	-----	15.0	9.3	20.0	18.2	19.3	15.0
Burns, Oreg.....	2	15.2	25.0	11.7	18.1	-----	16.7	19.7	19.4	15.9
Moro, Oreg.....	3	22.6	24.0	15.5	-----	-----	27.8	21.4	25.7	21.6
Davis, Cal.....	1	26.8	23.3	31.5	-----	-----	28.2	16.3	30.7	9.7
Irrigated districts:										
Newell, S. Dak.....	3	18.2	-----	21.7	16.2	13.7	-----	12.6	-----	-----
Huntley, Mont.....	2	47.0	-----	-----	-----	-----	45.1	35.6	-----	-----
Aberdeen, Idaho.....	3	43.0	-----	-----	-----	32.8	-----	52.1	-----	43.4
Fallon, Nev.....	2	28.9	-----	-----	-----	-----	-----	37.0	-----	38.5

YIELDS PER ACRE EXPRESSED IN PERCENTAGES OF YIELD OF MARQUIS.

Northern Prairie States:										
Ames, Iowa.....	2	100	249.5	-----	73.9	78.2	82.4	-----	-----	-----
Lincoln, Nebr.....	3	100	128.8	-----	-----	-----	94.9	-----	-----	-----
Brookings, S. Dak.....	3	100	151.0	84.1	50.2	65.7	81.6	-----	-----	-----
St. Paul, Minn.....	3	100	134.7	85.7	96.0	84.0	97.5	-----	-----	-----
Crookston, Minn.....	3	100	-----	94.4	-----	70.4	75.0	-----	-----	-----
Northern Great Plains area:										
North Platte, Nebr.....	3	100	180.7	117.3	-----	-----	40.4	-----	-----	-----
Akron, Colo.....	3	100	135.7	128.0	103.9	-----	102.7	-----	-----	-----
Archer, Wyo.....	3	100	135.2	126.5	84.5	64.8	97.7	-----	-----	-----
Newell, S. Dak.....	3	100	173.5	111.8	86.1	81.0	97.2	-----	-----	-----
Highmore, S. Dak.....	3	100	77.8	93.5	70.2	59.1	91.4	-----	-----	-----
Eureka, S. Dak.....	2	100	0	115.5	-----	55.8	74.4	-----	-----	-----
Edgeley, N. Dak.....	3	100	-----	121.7	94.8	89.6	-----	-----	-----	-----
Langdon, N. Dak.....	2	100	-----	137.9	78.7	-----	-----	-----	-----	-----
Williston, N. Dak.....	3	100	28.8	113.7	102.5	100.4	93.8	-----	-----	-----
Dickinson, N. Dak.....	3	100	25.7	134.6	92.9	85.6	88.6	-----	-----	-----
Moccasin, Mont.....	3	100	123.2	101.2	94.3	-----	103.8	-----	-----	-----
Western basin and coast areas:										
Nephi, Utah.....	2	100	262.5	119.5	104.8	-----	-----	-----	-----	-----
Aberdeen, Idaho.....	2	100	210.8	-----	107.9	66.9	143.8	131.0	138.8	107.8
Burns, Oreg.....	2	100	164.5	77.0	119.1	-----	109.8	129.5	127.6	104.6
Moro, Oreg.....	3	100	106.2	68.6	-----	-----	123.0	94.8	113.7	95.6
Davis, Cal.....	1	100	87.0	117.5	-----	-----	105.2	60.9	114.5	36.4
Irrigated districts:										
Newell, S. Dak.....	3	100	-----	119.2	89.0	75.3	-----	69.3	-----	-----
Huntley, Mont.....	2	100	-----	-----	-----	-----	96.0	75.8	-----	-----
Aberdeen, Idaho.....	3	100	-----	-----	-----	76.3	-----	121.1	-----	100.9
Fallon, Nev.....	2	100	-----	-----	-----	-----	-----	128.0	-----	133.2

^a Average for only two years.

The data are summarized briefly as follows:

Wherever hard red winter wheat can be grown in the sections discussed, it out-yields any spring wheat.

In the northern Prairie States the Marquis is the best variety of spring wheat. In the northern section of the Great Plains area durum wheats outyield spring common wheats. Among the latter the Marquis is the highest yielding variety.

West of the Rocky Mountains the Marquis is outyielded by the standard varieties of soft white spring wheat and by several newly introduced varieties. Under irrigation the Marquis has done fairly well in limited experiments east of the Rocky Mountains, but has not proved a good yielder at two stations west of this range.

MILLING AND BAKING QUALITY.

Experiments in milling and baking the Marquis and other standard hard spring wheats conducted by the North Dakota Agricultural Experiment Station ¹ in 1913 and 1914 and by the Minnesota Agricultural Experiment Station ² in 1913, have been published. An extensive series of experiments on the comparative milling and baking value of the Marquis and other spring-wheat varieties is now being conducted cooperatively by the North Dakota Agricultural Experiment Station and the Offices of Cereal Investigations and of Grain Standardization of the Bureau of Plant Industry.

The published data show that the Marquis wheat samples tested were equal or slightly superior in most respects to the samples of Fife, Bluestem, and Preston ("Velvet Chaff") wheats raised under similar conditions. A higher total yield of flour was obtained from the Marquis. The percentage of bran was less, while that of shorts was greater from the Marquis than from the three standard groups of spring common wheat. Compared with durum wheat, the Marquis is slightly lower in yield of flour and shorts but higher in yield of bran.

The baking quality of Marquis flour is high. It contains more crude protein than the flours of the three principal groups of spring common wheat. The amount of water absorbed by the Marquis flour in dough making also is high. These are important features in determining the expansive quality of the flour or its gluten. The loaf volume of the Marquis exceeds that of the other hard spring common wheats. There is comparatively little difference in the color, texture, and crumb of the Marquis and of the other spring common wheats.

In short, the data show the Marquis to be a first-class milling wheat.

¹ Ladd, E. F. Chemical and physical constants for wheat and mill products. N. Dak. Agr. Exp. Sta. Bul. 114, p. 273-297, 9 fig. 1916.

² Bailey, C. H. Marquis wheat. II. The milling quality of Marquis wheat. In Minn. Agr. Exp. Sta. Bul. 137, p. 9-14, illus. 1914.

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THE FLOW OF WATER IN WOOD-STAVE PIPE

By

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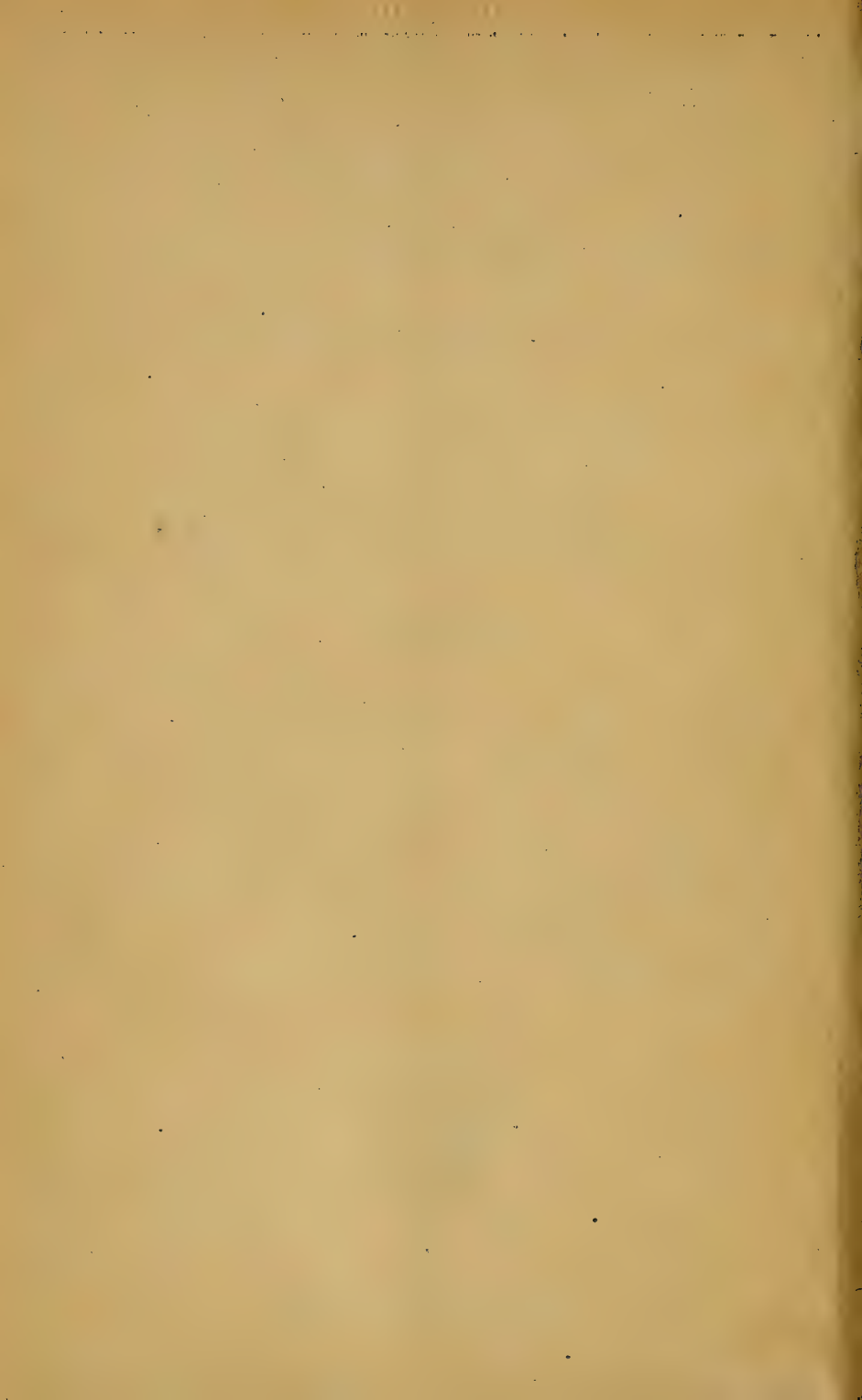
with discussion by

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BULLETIN No. 379

Contribution from the Bureau of Chemistry, CARL L. ALSBERG, Chief, and the
Office of Public Roads and Rural Engineering, LOGAN WALLER PAGE, Director

Washington, D. C.



August 4, 1916

DUST EXPLOSIONS AND FIRES IN
GRAIN SEPARATORS IN THE
PACIFIC NORTHWEST

By

DAVID J. PRICE, Engineer in Charge of Grain Dust Explosion Investi-
gations, Bureau of Chemistry, and E. B. McCORMICK, Chief,
Division of Rural Engineering, Office of Public
Roads and Rural Engineering

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UNITED STATES DEPARTMENT OF AGRICULTURE
BULLETIN No. 380

Contribution from the Bureau of Plant Industry
WM. A. TAYLOR, Chief.

Washington, D. C.

PROFESSIONAL PAPER

January 15, 1917

ENDOTHIA PARASITICA AND
RELATED SPECIES

By

C. L. SHEAR, Pathologist, and NEIL E. STEVENS, Pathol-
ogist, Fruit-Disease Investigations, and RUBY J. TILLER,
Scientific Assistant, Office of Investigations
in Forest Pathology

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BUREAU OF PLANT INDUSTRY.

Chief of Bureau, WILLIAM A. TAYLOR.

OFFICE OF INVESTIGATIONS IN FOREST PATHOLOGY.

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UNITED STATES DEPARTMENT OF AGRICULTURE
BULLETIN No. 381

Contribution from the Office of Markets and Rural Organization
CHARLES J. BRAND, Chief

Washington, D. C.

September 29, 1916

BUSINESS PRACTICE AND ACCOUNTS
FOR COOPERATIVE STORES

By

J. A. BEXELL, Dean, School of Commerce, Oregon Agricultural
College, Collaborator, Office of Markets and Rural Organiza-
tion, and W. H. KERR, Investigator in Market Business
Practice, Office of Markets and Rural Organization

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UNITED STATES DEPARTMENT OF AGRICULTURE
BULLETIN No. 386

Contribution from Office of Public Roads and Rural Engineering
LOGAN WALLER PAGE, Director

Washington, D. C.



September 11, 1916

PUBLIC ROAD MILEAGE AND REVENUES
IN THE MIDDLE ATLANTIC
STATES, 1914

A COMPILATION SHOWING MILEAGE OF IMPROVED AND UNIMPROVED ROADS; SOURCES AND AMOUNTS OF ROAD REVENUES; BONDS ISSUED AND OUTSTANDING; AND A DESCRIPTION OF THE SYSTEMS OF ROAD ADMINISTRATION AND FISCAL MANAGEMENT, AND OF OTHER FACTORS AFFECTING ROAD IMPROVEMENT IN EACH STATE

PREPARED JOINTLY BY THE DIVISION OF ROAD
ECONOMICS AND THE STATE COLLABORATORS
OF THE OFFICE OF PUBLIC ROADS AND
RURAL ENGINEERING

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1916

UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 387

Contribution from Office of Public Roads and Rural Engineering
LOGAN WALLER PAGE, Director

Washington, D. C.

February 20, 1917

PUBLIC ROAD MILEAGE AND REVENUES IN THE SOUTHERN STATES, 1914

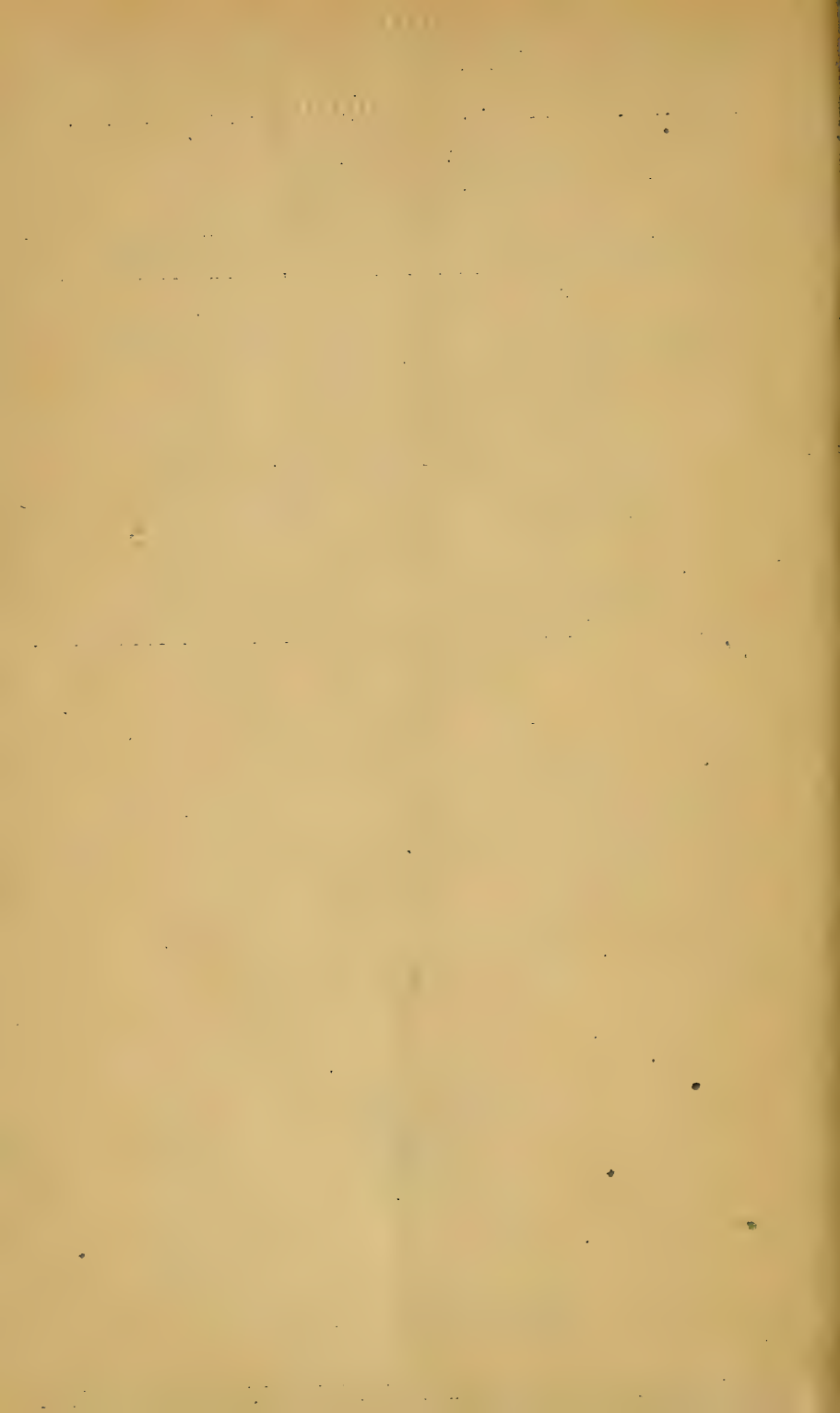
A COMPILATION SHOWING MILEAGE OF IMPROVED AND
UNIMPROVED ROADS, SOURCES AND AMOUNTS OF ROAD
REVENUES, BONDS ISSUED AND OUTSTANDING, AND A
DESCRIPTION OF THE SYSTEMS OF ROAD ADMINISTRA-
TION, FISCAL MANAGEMENT AND OTHER FACTORS AF-
FECTING ROAD IMPROVEMENT IN EACH STATE

Prepared Jointly by the
Division of Road Economics of the Office of Public Roads
and Rural Engineering, and State Collaborators

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UNITED STATES DEPARTMENT OF AGRICULTURE
BULLETIN No. 388

Contribution from the Office of Public Roads and Rural Engineering
LOGAN WALLER PAGE, Director

Washington, D. C.

January 8, 1917

PUBLIC ROAD MILEAGE AND REVENUES IN
THE NEW ENGLAND STATES, 1914

A COMPILATION SHOWING MILEAGE OF IMPROVED AND
UNIMPROVED ROADS, SOURCES AND AMOUNTS OF ROAD
REVENUES, BONDS ISSUED AND OUTSTANDING, AND A
DESCRIPTION OF THE SYSTEMS OF ROAD ADMINISTRA-
TION, FISCAL MANAGEMENT, AND OTHER FACTORS AF-
FECTING ROAD IMPROVEMENT IN EACH STATE

Prepared jointly by the
Division of Road Economics of the Office of Public Roads
and Rural Engineering, and State Collaborators

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UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 389

Contribution from the Office of Public Roads and Rural Engineering
LOGAN WALLER PAGE, Director

Washington, D. C.

May 10, 1917

PUBLIC ROAD MILEAGE AND REVENUES IN THE CENTRAL, MOUNTAIN, AND PACIFIC STATES, 1914

A COMPILATION SHOWING MILEAGE OF IMPROVED AND
UNIMPROVED ROADS; SOURCES AND AMOUNTS OF ROAD
REVENUES; BONDS ISSUED AND OUTSTANDING; AND
A DESCRIPTION OF THE SYSTEMS OF ROAD ADMINIS-
TRATION, FISCAL MANAGEMENT, AND OTHER FACTORS
AFFECTING ROAD IMPROVEMENT IN EACH STATE

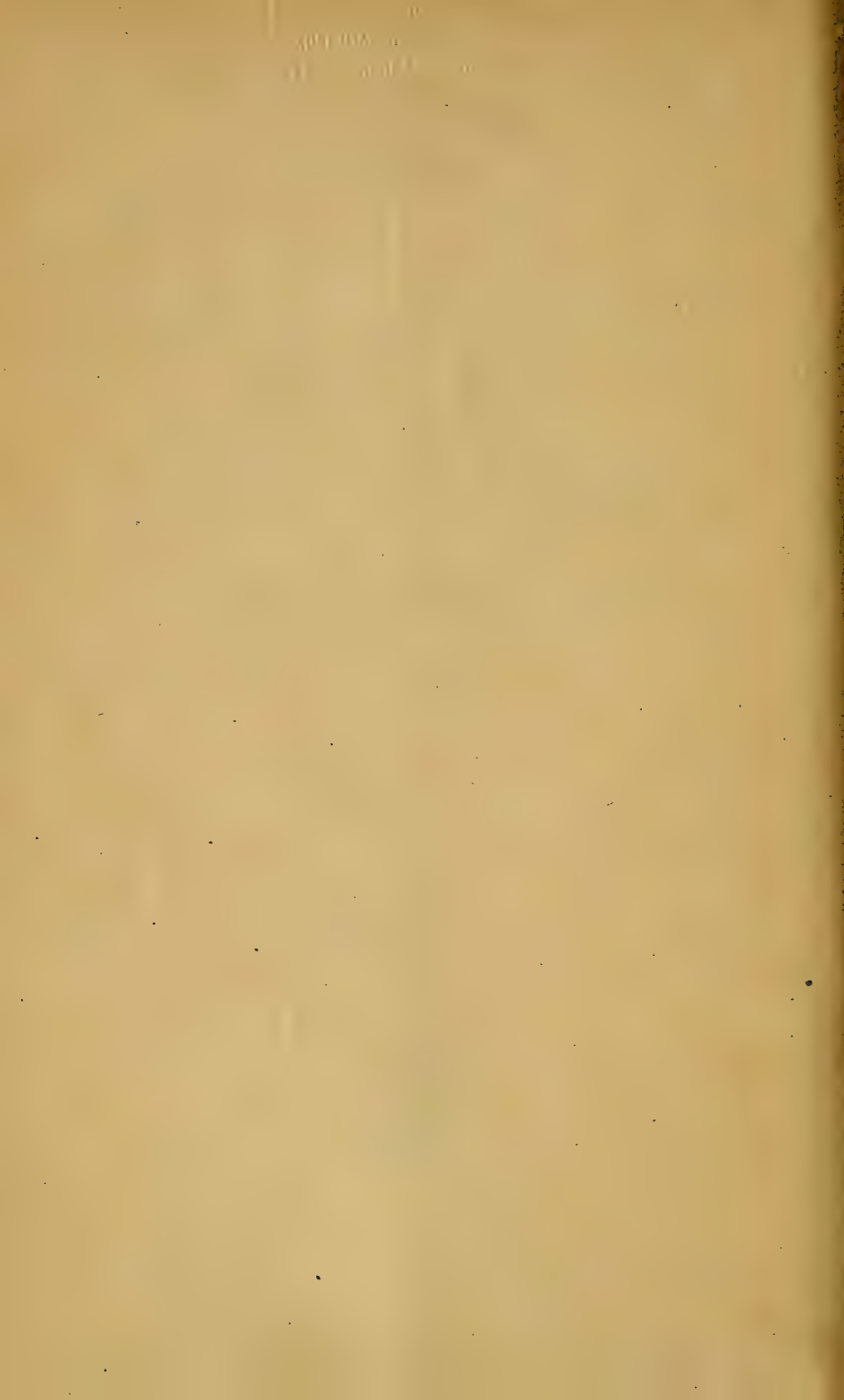
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and Rural Engineering, and State Collaborators

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UNITED STATES DEPARTMENT OF AGRICULTURE
BULLETIN No. 390

Contribution from the Office of Public Roads and Rural Engineering
LOGAN WALLER PAGE, Director

Washington, D. C.



January 12, 1917

PUBLIC ROAD MILEAGE AND REVENUES
IN THE UNITED STATES, 1914

A SUMMARY

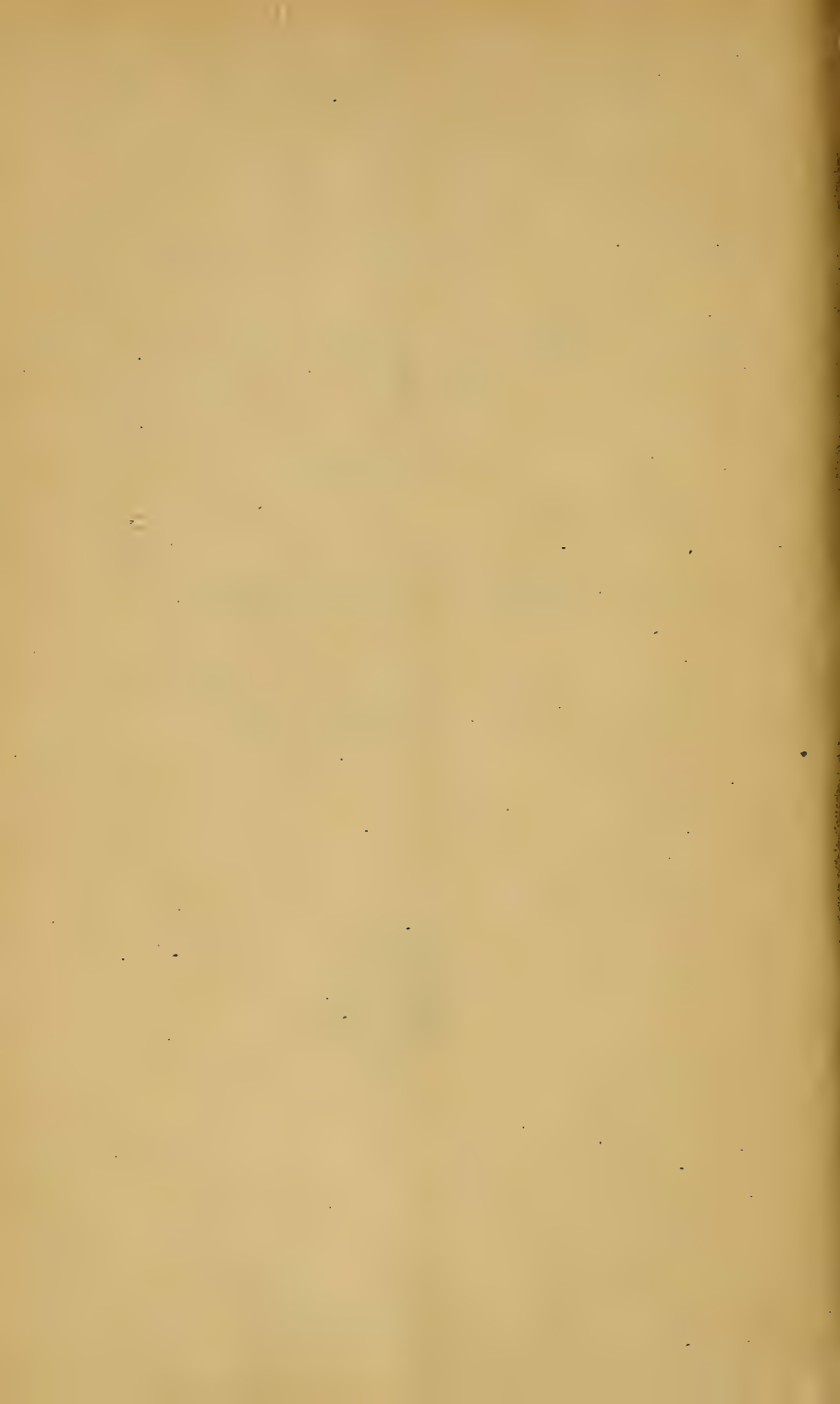
(Based upon Bulletins 386, 387, 388, and 389)

SHOWING FOR EACH STATE TOTAL AND SURFACED MILEAGE OF
PUBLIC ROADS AT THE CLOSE OF 1914, REVENUES FOR ROADS
AND BRIDGES IN 1914, STATE AND LOCAL ROAD AND
BRIDGE BONDS OUTSTANDING JANUARY 1, 1915,
AND OTHER RELATED DATA

PREPARED JOINTLY BY THE DIVISION OF ROAD
ECONOMICS OF THE OFFICE OF PUBLIC
ROADS AND RURAL ENGINEERING
AND STATE COLLABORATORS



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1917



UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 391

Contribution from the Bureau of Chemistry
CARL L. ALSBERG, Chief

Washington, D. C.

PROFESSIONAL PAPER

December 10, 1918

ACCURACY IN COMMERCIAL GRADING
OF OPENED EGGS

By

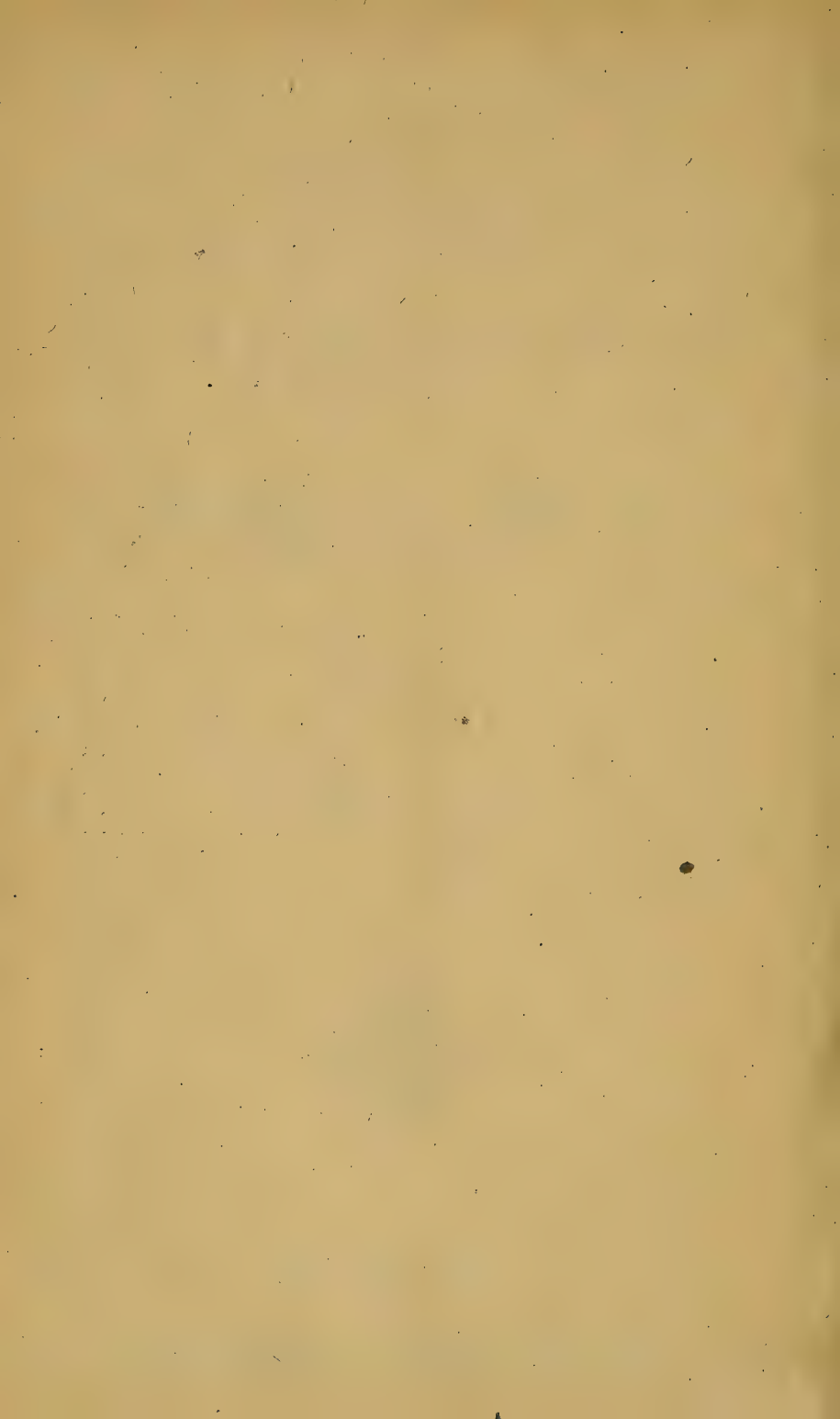
M. K. JENKINS, Assistant Bacteriologist, and
NORMAN HENDRICKSON, Assistant Chemist,
Food Research Laboratory

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1918



UNITED STATES DEPARTMENT OF AGRICULTURE
 BULLETIN No. 393

Contribution from Office of Public Roads and Rural Engineering
 LOGAN WALLER PAGE, Director

Washington, D. C. ▼ October 23, 1916

ECONOMIC SURVEYS OF COUNTY
 HIGHWAY IMPROVEMENT

A COMPILATION AND ANALYSIS OF DATA IN EIGHT
 SELECTED COUNTIES, SHOWING COMPARATIVE
 FINANCIAL BURDENS AND ECONOMIC BENEFITS
 RESULTING FROM HIGHWAY IMPROVEMENT
 DURING A PERIOD OF YEARS

By
 J. E. PENNYBACKER, Chief of Road Economics, and
 M. O. ELDRIDGE, Assistant in Road Economics

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Y. S. A. (1871)

1871

1871

1871

UNITED STATES DEPARTMENT OF AGRICULTURE
BULLETIN No. 394

Contribution from Office of Markets and Rural Organization
CHARLES J. BRAND, Chief

Washington, D. C.



November 3, 1916

A SURVEY OF
TYPICAL COOPERATIVE STORES
IN THE UNITED STATES

By

J. A. BEXELL, Dean, School of Commerce, Oregon Agricultural College;
HECTOR MACPHERSON, Director, Bureau of Markets, Oregon Agricultural College; and W. H. KERR, Investigator
in Market Business Practice, Office of Markets
and Rural Organization, United States
Department of Agriculture

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1916

UNITED STATES DEPARTMENT OF AGRICULTURE
BULLETIN No. 395

Contribution from the Bureau of Plant Industry
WM. A. TAYLOR, Chief

Washington, D. C.

PROFESSIONAL PAPER

January 18, 1917

PEACH SCAB AND ITS CONTROL

By

G. W. KEITT, formerly Scientific Assistant
Fruit-Disease Investigations

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1881

UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 398

Contribution from the Bureau of Plant Industry
WM. A. TAYLOR, Chief

Washington, D. C.



October 12, 1916

CEREAL EXPERIMENTS AT THE
JUDITH BASIN SUBSTATION
MOCCASIN, MONT.

By

N. C. DONALDSON, Scientific Assistant
Office of Cereal Investigations

(In cooperation with the Montana Agricultural Experiment Station)

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UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 400

Contribution from the Bureau of Plant Industry
WM. A. TAYLOR, Chief

Washington, D. C.

PROFESSIONAL PAPER

October 26, 1916

EXPERIMENTS WITH MARQUIS WHEAT

By

CARLETON R. BALL, Agronomist in Charge, and J. ALLEN CLARK,
Scientific Assistant, Western Wheat Investigations,
Office of Cereal Investigations

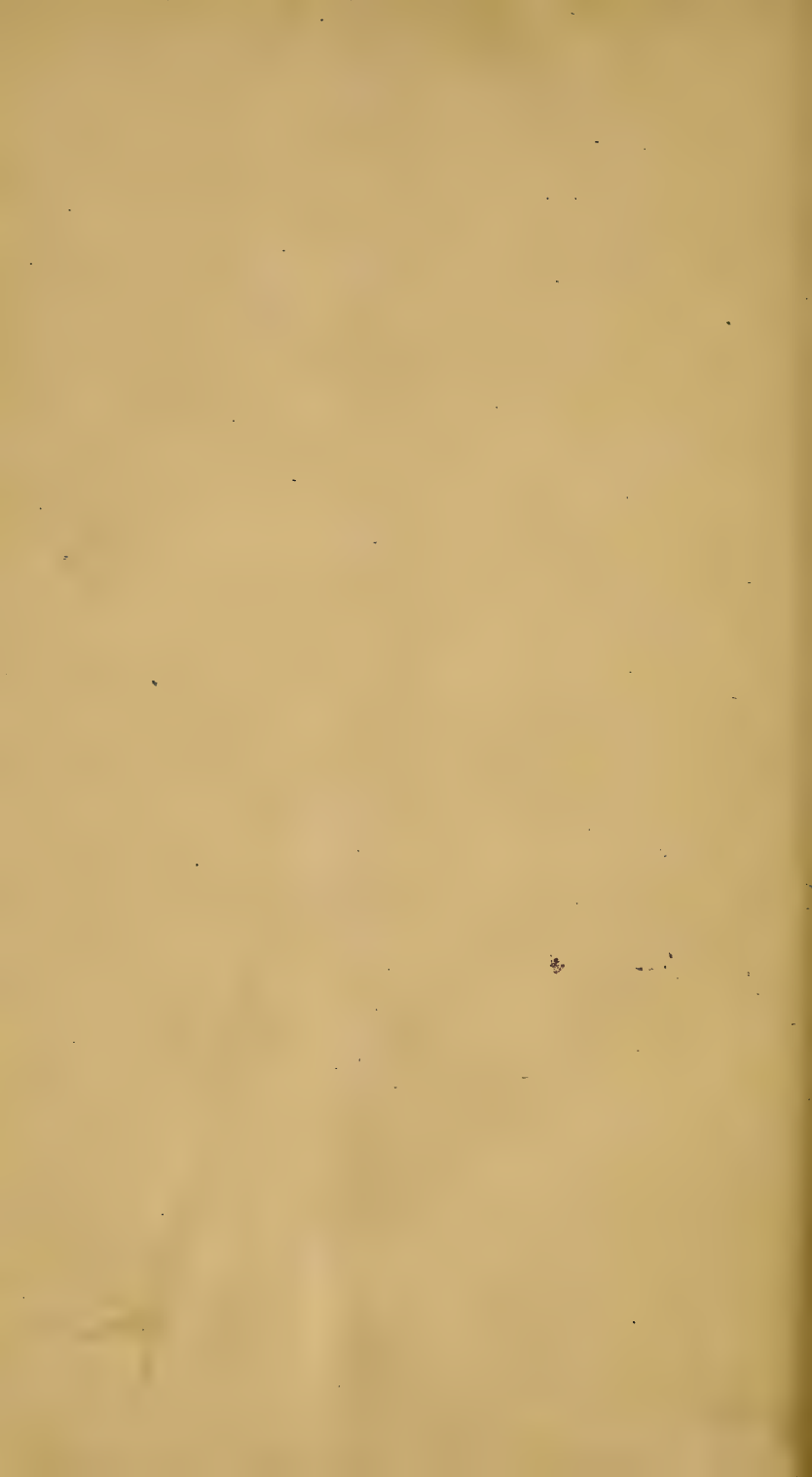
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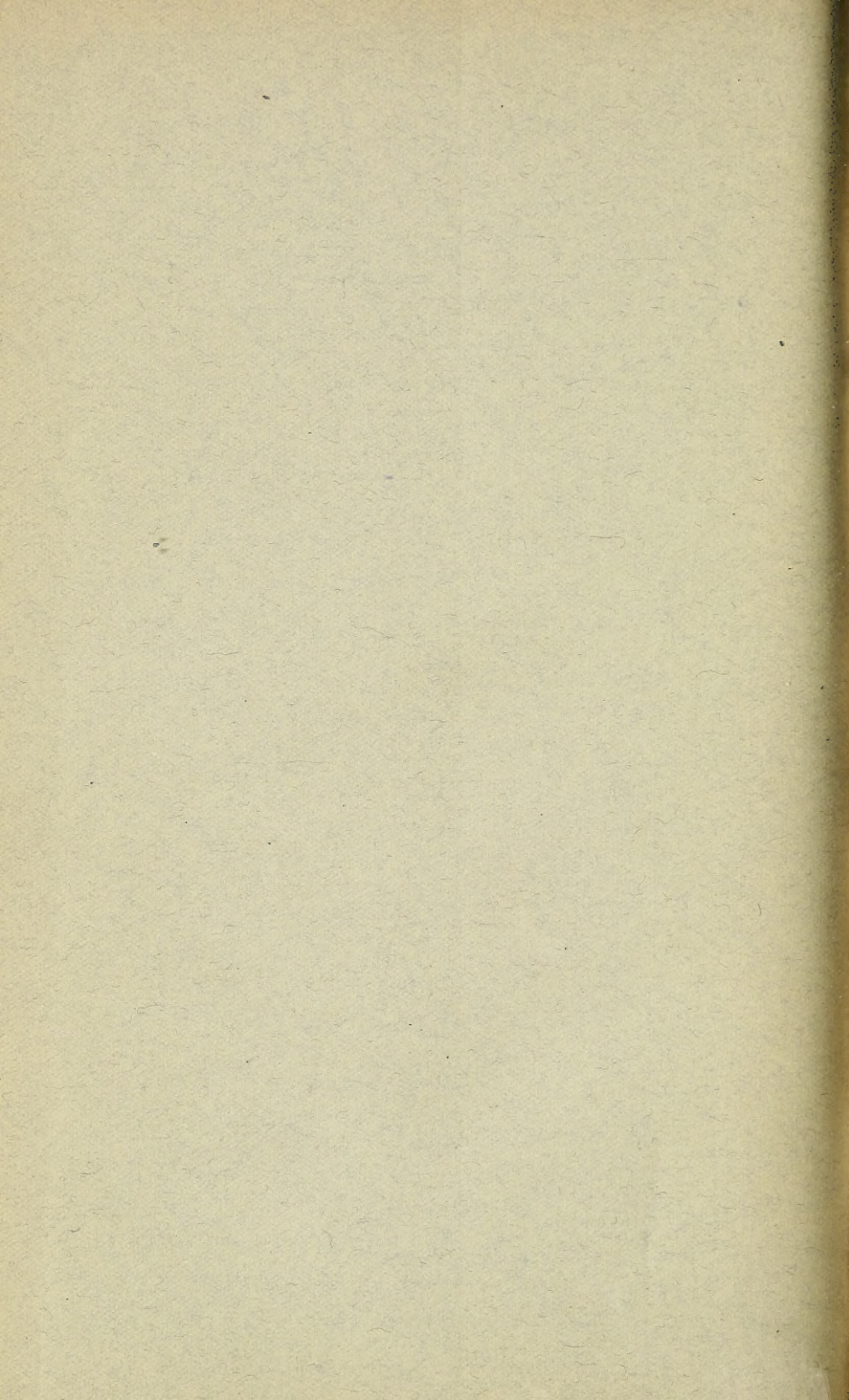
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